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PIANO TECHNIQUE AS A MANIFESTATION OF MOTOR CONTROL AND LEARNING: AN INVESTIGATION FROM THE PERSPECTIVES OF THE MOTOR AND ACTION SYSTEMS THEORIES

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Submitted in fulfilment of part of the requirements
for the degree

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At liquidas avium voces imitarier ore
ante fuit multo quam levia carmina cantu
concelebrare homines possent aurisque iuvare.
et zephyri, cava per calamorum, sibila primum
agrestis docuere cavas inflare cicutas.
inde minutatim dulcis didicere querellas,
tibia quas fundit digitis pulsata canentum,
avia per nemora ac silvas saltusque reperta,
per loca pastorum deserta atque otia dia.
[sic unumquicquid paulatim protrahit aetas
in medium ratioque in luminis erigit oras.]
haec animos ollis mulcebant atque iuvabant
cum satiate cibi; nam tum sunt omnia cordi.

- Titus Lucretius Carus (*c*.98 - *c*.55 B.C.), *De Rerum Naturam*, Liber V [1379-1391]

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SUMMARY

TITLE: Piano technique as a manifestation of motor control and learning: an investigation from the perspectives of the motor and action systems theories

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Many reasons can be cited for resorting to motor behaviour science in psychology as a departure point for investigating piano technique. This study compares the merits of the motor and action systems approaches to motor control and learning in order to assess which approach could be most valuable in addressing problems of piano playing.

The study commences with an investigation into the traditional motor systems perspective of motor control. Discussions are rather general and multi-faceted in order to enhance understanding of action theorists' criticisms of the motor view - an approach also necessitated by the lack of research involving piano playing.

Three stages of human information-processing and the way they are influenced by interference are examined. In the final, i.e. response-programming stage, movements can only be launched in discrete bursts; this, however, does not influence fluency and continuity in piano playing, because a response can consist of many subsidiary movements controlled by a motor program. In the response-execution stage following information-processing, movements are organized with a powerful underlying temporal structure. Only one such structure can be sustained by the motor program at a time, explaining the difficulty of executing polyrhythms in piano playing. The generalized motor program concept can account for certain easily coordinated technical constructs in piano playing. Also, grounds exist for postulating that rhythm and timing in piano playing are regulated by an internal clock.

Following discussions on the relative importance of three types of intrinsic feedback for piano playing and the pointing out of techniques for giving extrinsic feedback, Adams's closed-loop theory and Schmidt's schema theories for motor learning under the motor systems approach are critically examined. Methods are described for applying schema theory concepts to musical instrument practice. Motor memory, apparently, is not well understood.

Action theorists regard the motor systems application of the computer metaphor to human motor

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behaviour and the motor programming notion as incorrect. The concept of functionally-defined actions consisting of postures and movements, which in themselves are actions, is presented. The ecological view, based on Gibson, that human information-pickup from the environment is direct, without elaborate central processing, is discussed. Apparent common denominators between two prominent "methods" for piano playing and action systems theory are pointed out.

Most aspects of action systems theory still need to be tested; much uncertainty is also prevalent on action learning.

Under the motor systems approach, various scientifically-based premises exist for structuring piano practice, applying to *inter alia* massed vs. distributed practice, blocked vs. random practice, variability in practice, slow practising of rapid passages, and practising "in rhythms". If action theory is correct in that the motor programming notion is wrong, most of these premises could lose their scientifically-based claims to validity; so will schema theory. Unfortunately, action theory apparently cannot offer any scientifically verified alternatives yet.

Much more research will be necessary for either choosing a particular theory or establishing a fusion between theories as a basis for piano-technical learning.

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SAMEVATTING

TITEL: Klaviertegniek as a manifestasie van motoriese beheer en leer: 'n ondersoek vanuit die perspektiewe van die *motor systems*- en *action systems*-teorieë

OUTEUR: Jan Pieter Jacobs

LEIER: Prof. S. Grové

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Verskeie redes kan aangevoer word vir die keuse van *motor behaviour science* in die psigologie as vertrekpunt vir 'n ondersoek na klaviertegniek. Hierdie studie vergelyk die *motor systems*- en die *action systems*-benaderings tot motoriese beheer en leer ten einde te bepaal watter benadering van die meeste nut sal wees vir 'n ondersoek na klaviertegniese vraagstukke.

Eerstens word die tradisionele *motor systems*-perspektief van motoriese beheer ondersoek. Besprekings is van 'n betreklik algemene aard en dek verskeie fasette om begrip van die *action*-teoretici se kritiek van die *motor*-perspektief te bevorder. Hierdie benadering word voorts genoodsaak deur 'n tekort aan navorsing met betrekking tot klavierspel.

Drie fases van menslike inligtingverwerking en die invloed daarop van interferensie word ondersoek. Tydens die laaste -, of responsprogrammeringsfase, kan bewegings slegs in diskrete sarsies geïnisieer word. Vloeiendheid en kontinuïteit in klavierspel word egter nie geraak nie aangesien 'n bewegingsrespons uit verskeie ondergeskikte bewegings, beheer deur deur 'n motoriese program, kan bestaan. Gedurende die responsuitvoeringsfase na inligtingsverwerking word bewegings georganiseer met 'n sterk onderliggende tydstruktuur. Slegs een tydstruktuur kan op 'n keer deur die motoriese stelsel hanteer word, wat verklaar waarom dit moeilik is om poli-ritmes in klavierspel uit te voer. Die veralgemeende motoriese program kan bepaalde maklik-uitvoerbare tegniese konstruksies in klavierspel verklaar. Gronde bestaan vir die stelling dat ritme en tydsberekening in klavierspel deur 'n interne klok gereguleer word.

Die relatiewe belangrikheid vir klavierspel van drie tipes intrinsieke terugvoer word bespreek en tegnieke vir ekstrinsieke terugvoer word uitgewys. Hierna word Adams se geslotelus-teorie en Schmidt se *schema*-teorie vir motoriese leer in die konteks van die *motor systems*-benadering krities ondersoek. Wyses vir die toepassing van *schema*-konsepte ten opsigte van musiekinstrument-oefening word uitgelig. Klaarblyklik is nie veel bekend oor die motoriese geheue nie.

Action-teoretici beskou die *motor systems*-toepassing van die rekenaarmetafoor op die mens as

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onjuis. Voorts ontken hulle die bestaan van motoriese programme. Die konsep van funsioneel-gedefinieerde *actions* bestaande uit *postures* en *movements*, wat *actions* in eie reg is, word uitgelig. Gibson se ekologiese perspektief dat die mens direk inligting uit die omgewing opneem, sonder uitgebreide inligtingverwerking, word bespreek. Faktore in gemeen tussen twee "metodes" vir klavierspel en *action systems*-teorie word uitgewys.

Die meeste aspekte van *action systems*-teorie moet nog aan toetsing onderwerp word; heelwat onsekerheid bestaan ook rondom *action* motoriese leer.

Die *motor systems*-benadering huisves verskeie wetenskaplik-gebaseerde veronderstellings waarvolgens klavieroefen gestruktureer kan word; hierdie veronderstellings het onder andere betrekking op *massed* vs. verspreide oefen, *blocked* vs. willekeurige oefen, veranderlikheid in oefen, stadige oefen van vinnige passasies en oefen in "ritmes". As *action*-teorie korrek is omtrent die verkeerdheid van die *motor*-benadering, kan die wetenskaplik-teoretiese verantwoordbaarheid van die meeste veronderstellings daarmee heen wees. Ongelukkig kan *action*-teorie klaarblyklik nie wetenskaplik-bewese alternatiewe verskaf nie ten spyte van bepaalde belowende insigte.

Heelwat meer navorsing word benodig ten einde 'n bepaalde teorie of samesmelting van teorieë te kies as 'n grondslag vir klaviertegniese leer.

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CHAPTER 1

INTRODUCTION

1.1 A brief survey of thought concerning piano technique since 1750

An understanding of the current thoughts on piano technique prevalent among pianists and teachers requires some insight into the way piano technique has developed over the better part of three centuries. Historical surveys of the evolution of piano technique, varying in scope and completeness are fairly common, having been performed in the second half of the 20th century by *inter alia* Boardman (1954), Kloppenburg (1960), Kochevitsky (1967), Künkel (1965), and Jaeken (1990). In order to heed Stangeland's (1980a:37) rather astute notion that "[i]t is the thinking musician, the thinking pianist in particular, who will not discount entirely the contribution to technical thought and practice of any one school of thought", some of the most important trends will be pointed out here briefly.

According to Stangeland (1980a:32), one of the first schools of technique emanated from the characteristics of the technique used to play the earlier keyboard instruments. Since the fingers were sufficient means to master these earlier instruments, this school is named the *finger school*. Major treatises that signify the beginning and the ending of the period in which this mode of thought predominated, are the *Essay on the True Art of Playing Keyboard Instruments* of 1753 by C.P.E. Bach, and the *Complete and Practical Pianoforte School* of 1837 by Czerny[1]. According to Kochevitsky (1967:3), exponents of the finger school held that only the fingers should be used, keeping the upper parts of the arm stationary. The development of technical facility was regarded as purely a mechanical procedure, requiring many hours of incessant, repetitious daily practice. The teacher was regarded as the absolute and final authority on matters such as the solving of technical problems and scheduling of practice. Stangeland (1980a:32), however, points out that the thoughts on technique of C.P.E. Bach, who employed a close finger technique, apparently extended beyond the stereotyped use of the fingers as suggested by Kochevitsky:

> A close finger technique usually suggests participation of other parts of the playing mechanism in depressing keys ... certainly Bach's reference to the hand (possibly even the arm) stroke is

[1]Boardman (1954) considers this school to have been the major direction of thought for the first century in the history of piano technique, i.e. from 1750 to 1850.

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proof that he advocated more than finger action.

So did the views of many others, if their insistence on a singing tone for the execution of long musical phrases (Stangeland 1980a:33) is taken as the criterion.

Stangeland (1980a:33) notes that the technical principles of the finger school have been subjected to misinterpretation in that later authors have regarded the role of the fingers as greatly over-emphasized by the finger school; "[g]ranted, ... [the fingers] are on the periphery of the playing apparatus, but without them the piano simply could not be played". Even though power can be initiated somewhere else in the body, the role played by the fingers is always an integral part of piano playing, and as such should never be neglected.

Referring to the influence of the views of finger school exponents on later generations of pianists, Stangeland (1980a:32) makes an important comment on the division into time periods of the history of the development of piano technique:

> [Division into time periods] is not to suggest that there were no proponents of the school of finger technique after that time nor that certain features of this school of thought are not integrated into living techniques of some of the great performers of today. Nor are we able to assume that during the epoch of finger technicians there were not those who anticipated other schools of technical thought, consciously or unconsciously.

The second important school of piano technique is the school of the arm and its weight, or the *relaxation school.* Precursors of this school included Kalkbrenner, Kohler, and Kullak, but the most important figure among them was probably Ludwig Deppe, regarded by Stangeland (1980a:34) as "[p]erhaps the most systematic piano theorist of the nineteenth century". Stangeland (1980a:36) summarizes the essentials of Deppe's rather visionary approach, which anticipated many later writings on technique, as follows:

> ... his ideas encompassed ... the importance of critical listening to sounds produced and their relationships, the coordination not only of the physical mechanism itself but the coordination of mind and playing apparatus, stressing the necessity of developing control from the brain to the fingertips. His theory of movement was highlighted by continuously curved movements rather than angular straight-line movements and he was opposed to striking the keys with equal hitting power as had been advocated by some representatives of the finger-technique school.

Kochevitsky (1967:9) however notes that Deppe's ideas were subjected to misrepresentation by some of his followers. Also, his lack of lucidness in explaining his beliefs lead to misunderstanding; the most notorious example probably being the matter of the free fall of the arm, which for rather obvious reasons should be regarded in a metaphorical sense rather than taken literally (Kochevitsky 1967:8).

According to Stangeland (1980a:36), Matthay and Breithaupt were the leading exponents of the school of the arm and its weight. Their insistence on their students listening to themselves and

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approaching technical problems intellectually had a positive influence on later generations (Stangeland 1980a:37). Matthay (1947:12) advocated the bond between music and technique and "... the need for a particular mental-muscular association and cooperation for every musical effect" (Stangeland 1980a:36). His concept of relaxation did not disregard the role of the fingers, as can be deduced from his statement that (Matthay 1924:77) "[w]e must acquire the power to *use* our fingers and hands quite independently of any downward-acting arm-force, and even independently of arm-weight". According to Stangeland (1980a:37), Breithaupt made a considerable contribution by pointing out fallacies of the finger school such as fixed hand positions, and by stressing that the arm's movement versatility, i.e. for lateral, vertical, and rotational motions, could lead to more physical ease in piano playing. Stangeland singles out, as probably Breithaupt's most advanced idea, his notion that

> ... all fingerings ought to result automatically from natural movements. Such a theory depends, of course, upon a discernment of what is natural or unnatural for a given individual and is therefore open to question.

Out of the relaxation school originated a direction of thought in which the emphasis was placed on the coordination of all the body parts required for technical execution (Stangeland 1980a:37). Important exponents of this school included Gát, Ortmann, Fielden, and others, whose writings intended "... to stimulate the aspiring pianist to search out and study for himself where truth resides". Although this school is usually associated with 20th century technical thought, some earlier teachers and pianists were probably aware of its advantages as well. According to Stangeland (1980a:37), the common denominator between these authors was a belief in the "... importance and indispensability of the coordination of physical parts themselves, as well as the coordination of the physical playing mechanism with the ear, the mind, and the nervous system". A predecessor of this school who made some noteworthy contributions, Oscar Raif, showed through experiment that the demands made on an individual finger in piano playing with respect to agility, usually is much less than its natural capability (Kochevitsky 1967:12).

Coexisting with the coordination-movement school was the psycho-technical school, who stressed "... psychological and nerve factors in the development of technique" (Stangeland 1980a:37). An important precursor was Steinhausen, who held that practising is "first and foremost ... a psychic process" because all muscular activity is initiated and controlled by the central nervous system (Kochevitsky 1967:13). Prominent exponents of this school, which is essentially concerned with "... how the conscious mind can influence the subconscious in the realization of the musical substance of the piece being performed" (Stangeland 1980a:37), included Busoni, Bardas, Egon Petri, and pianists like Schnabel, Godowsky, and Gieseking. Extreme manifestations of this school of thought could however induce one to "... wonder over the necessity of physical practice at all" (Stangeland 1980a:37). According to Kochevitsky (1967:16), the psycho-technical approach generally held that technical problems should not be divorced from their musical purpose and that different technical

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problems should be attempted from different points of view. Muscular sensation is more important than observation of movement form. All parts of the pianist's bodily apparatus should be used freely and completely in order to establish the desired musical purpose in a convenient way (Kochevitsky 1967:16-17). Also, most hands can be considered sufficient equipment for establishing an advanced technique "... because of the brain behind the hands" (Kochevitsky 1967:17). All facilities should be employed in an interacting manner for achieving meaningful movements: "... the inner musical imagination, the innervation of movement, muscular sensations, and careful and critical listening to the results" (Kochevitsky 1967:16).

1.2 Statement of problem and purpose of study

The purpose of the present study is to investigate and contrast the potential value of two theoretical viewpoints from motor behaviour science in psychology for addressing the motor[2], i.e. technical, problems of piano playing. The term *technical* is used here in its broadest sense to include any problem involving muscular movement in piano playing.

Many reasons can be brought to the fore for reverting to psychology in order to address the problems of piano playing. Some of the most important of these reasons will now be stated below.

The vast majority of books that have been written on piano technique employs a physiological approach to the solving of technical problems; according to Lee (1977:3), "... most books on technical theories begin and end on physiological discussions of piano playing mechanics". Kochevitsky (1967:18) endorses this observation by stating that

> [f]or two hundred years pedagogical thought looked to the pianist's playing apparatus - to muscle work, to positions and movements of arms, hands and fingers - for the solution of all technical problems.

The problem with such an approach is that instructions from teachers to students - or, for that matter, instructions found in the plethora of books written by pedagogues and performing artists from their own experience - "[n]o matter how well-intentioned", have the potential to mislead the student (Stangeland 1982:38). The most obvious reason for this is simply that it is extremely difficult to convey verbally how complex, highly refined movement patterns have to be executed by the (equally complex) muscular playing apparatus of another player. As Ortmann explained in a personal correspondence to Gerig (1974:412) about his investigation into the "whys and wherefores of individual technical variations",

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[2]The term *motor* implies "causing or imparting motion" or "... involving muscular movement" (The Penguin English dictionary 1985:537).

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> [t]he explanations given me were so often the subjective expression of the player himself that the underlying physiological facts were unintelligible, nor was there agreement among the pupils even of any one teacher.

As suggested above, the rather unpredictable factor of individual differences in physical apparatus and ability causes the generality of the physiological approaches to be questioned. That individual differences in performing even relatively simple tasks should not be underestimated, was illustrated using scientifically-based means by McArthur (1988:1692-A): in an experiment, involving a computer analysis of the movements employed by two highly skilled pianists playing an elementary piece, she found little similarity between the movement patterns of the two subjects. Thus, Gát's (1958:5) observation that the main fault of the majority of books on piano playing, is that they rely too much on the individual experiences of the authors, does not come entirely unexpectedly.

It is of considerable interest to note that certain physiological strategies for enhancing piano technique seem to persist in being widely employed in spite of clear indications in the literature of their detrimental effects. One such practising strategy in particular - which is aimed at obtaining the intertwined properties commonly referred to as finger strength and finger individuality - can be traced back to at least as early a piano teacher as Clementi; it involves (Kochevitsky 1967:3) each finger striking its key repeatedly while the other four fingers hold down their keys in the five-finger position. Various authors have pointed out that exercises based on these principles can be highly detrimental; Neuhaus (1973:85), for instance, inquires

> ... how many hundreds and thousands of pitiful beginners ... when brought by their teachers into contact with the keyboard for the first time tried to turn their living hand with its nerves, muscles, flexible joints and pulsating blood, into a piece of wood with curved hooks ...

Sandor (1981:158-159), in agreement with Neuhaus, identifies as reason for the harmful effects of the above-mentioned exercises, the fact that finger and arm muscles are forced to function in a manner other than antagonistically, thus giving rise to severe muscle tension. Some authors even go as far as to question the principle behind the exercise; Prostakoff and Rosoff (1969:7) observe that

> ... let the student be taught that he needs "strong and independent fingers, and a steel-like wrist" and from then on, all too often, his musical goose is cooked!

It is therefore rather disconcerting, giving the convincing nature of the arguments above, to find in the recent literature on piano methodology that similar, if not identical, "finger independence studies" are prescribed or endorsed by eminent authors, for example Bastien (1977:244).

The above arguments bring another problem to the fore, namely the vastness of a literature in which a large variety of viewpoints, often on the same problems, is scattered throughout many volumes. Furthermore,

> ... points of view of individual authors are sometimes narrowly based, without positive consideration of the value of past or contemporary technical approaches. Therefore, much of what is written is not helpful unless it is read in conjunction with the writings of others ...

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(Stangeland 1980b:40)

1.3 Perspectives from which the present investigation is conducted

While it is noted that the practical wisdom of pianists and teachers should by no means altogether be disregarded or discarded, another approach to the complex motor problems of piano technique clearly needs to be adopted. Taubman (Schneider 1983:21) is rather frank on this matter:

> [w]hy should music be left in the Dark Ages? Mathematics and science have moved into the 20th Century, while 300 years of piano pedagogy have been handed down without research or evaluation. We can't afford the luxury of every teacher having his own untested theories of technique. The whole tradition must be weighed, codified, and tested against our contemporary knowledge of the basic principles governing body movement and the mechanical laws governing the piano.

Other authors clearly feel the same way; Kochevitsky[3] (1967:18), for example, is of the opinion that "... the main attention of thoughtful pianists and piano teachers" should be focused on the activities of the central nervous system. Bridges (1985:iii) sets down guidelines for developing "... a cognitively-oriented concept of piano technique" by integrating means obtained from the fields of psycho-physiology, motor behaviour science and psychology of consciousness into a framework of performance goals. The advantages for the pianist offered by knowledge of these fields of psychology can be described as follows (Bridges 1985:iii):

> *Psycho-physiology* offers the pianist evidence for relying as much as possible on reflex activity in developing technical skill. *Motor behavior science* provides a model with which a pianist can analyze his own internal processes during practise and performance. *Psychologies of consciousness* provide insights into how the mind can help or hinder those internal processes. [Italics added.]

According to Bridges (1985:18), concepts from psychology such as those mentioned above are by no means alien to the field of piano technique, because all writings on piano technique have some sort of psychological basis, whether the writer consciously intended this or not: "He [the writer] may assume too much psychologically or assume wrongly, but nonetheless ... every piano method is basically a conceptualization of motor behavior". The fact that such a wide variety of piano methods have seen the light in this century can in fact be attributed, at least in part, to a poor understanding of the psychological principles underlying motor control and learning (Bridges 1985:19).

[3]Bridges (1985:48) points out that Kochevitsky's understanding of motor skill development is based largely on the Pavlovian school of reflexology, "... which has fallen out of use in present day psychophysiology" - thus rendering his viewpoint of this problem, proposed in 1967, outdated. By directing attention to the mind in the solving of technical problems, however, Kochevitsky has nevertheless made a lasting contribution to this field.

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Bridges (1985:2) notes that motor behaviour science has never been seriously applied to the study of piano technique; pianists have rather used formal psychology in order to address the problem of performance anxiety and to aid the learning and memorizing of music.

According to Sidnell (1986:7), music educators have for quite some time been aware of the need for and importance of research into motor learning as pertaining to music education. It is not difficult to realize that the movements required for musical instrument performance are probably among the most demanding and complicated that can be expected of the human body -

> [e]ven without the music reading process present, music performances by ear, memory, or improvisation require long chains of precise motor activity, always with constant, sophisticated auditory monitoring.

Sidnell emphasizes that the interest of the music education community in motor behaviour research has unfortunately not transcended the level of mere lip service;

> [w]hen one surveys the research literature in music education, the paucity of systematic investigation by music educators of motor learning problems is alarmingly evident. For all our verbal dedication to the importance of motor learning to rhythmic development, for example, ... [little] bibliography of significance [can be provided].

Two reasons are identified by Bridges (1985:5-6) for the lack of research effort into the motor skills of piano playing in particular. The first is that it has long been taken for granted in Western culture that humans have total control over voluntary motor responses, implying that the most effective way of developing skills involving coordination is through conscious manipulation of the limbs. The second reason is the negation of the study of mental processes in the behavioural psychology approach to movement science that was prevalent for the largest part of this century. As Bridges puts it,

> [b]ecause conscious mental activity obviously plays such an enormous role in the psychological aspects of piano technique, it is easy to see how the behavioral approach would give disappointing results to any pianist looking for a scientific answer to his problems.

As mentioned earlier, this thesis will focus on *motor behaviour science*, which is one of the fields of psychology suggested by Bridges for developing a cognitively-orientated concept of piano technique. In particular, the disciplines of *motor control* and *motor learning* will be addressed, with special reference to their manifestations in piano technique. These disciplines will be investigated from two contrasting perspectives, namely the more "traditional" *motor systems theory*, and the newer *action systems theory*.

Although Adams (1987:41) is of the opinion that motor control "... is a child of physiology and of information processing in psychology, neither of which have had much interest in learning", Schmidt (1988b:4) indicates that neither motor control nor motor learning should be studied in isolation: "I see no good justification ... for separating the study of motor learning from the study

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of movement or of motor control in general, as this artificial separation inhibits the understanding of both issues". In the present study, therefore, although motor control and learning will be discussed in separate chapters, it is inevitable that some of the subject material will overlap in order to ensure a complete representation of the matter at hand.

The *motor systems approach* to motor control and learning is characterized by the use of information-processing models adopted from communications engineering and the notion that all movement is built up out of elementary neuro-behavioural units (Reed 1988:46). It holds that all action is centrally controlled, for example by means of a motor program. The motor approach can be described as the "traditional" approach, and can also be referred to as the man/machine approach, due to the fact that most of its concepts are gleaned from control and computer engineering.

The goal-orientated *action systems approach*, on the other hand, is defined by Reed (1988:46) as

> that [functionally based] area of motor skill research that emphasizes task orientation and offers a taxonomy of acts based on goals ... but ... adds the assertion that evolution has resulted in a number of autonomous action systems which work in their own way to achieve specific functions.

Any action is made up of components which have a specific function and would themselves count as actions (Reed 1988:49). The action theorists reject the motor approach and the existence of motor programs; Meijer and Roth (1988:xi) thus aptly describe the significance of the advent of the action approach as follows: "[o]nce in a while, the psychological community is disturbed by the emergence of a group of researchers who proclaim that Psychology has been looking in the wrong direction altogether ...".

Throughout the thesis the approach to these topics will be critical, i.e. criticism of the motor systems approach from the action systems viewpoint will be presented, and vice versa.

1.4 Research strategy and delimitation of subject material

The nature of this thesis will be exploratory, consisting of a study of relevant literature on piano technique and psychology. As the main point of departure of this study is that of a musician, conclusions on the significance, and criticisms on the work done by psychologists in the motor behaviour field, will be restricted to the opinions published in this regard by their peers.

Limiting the present investigation to motor control and learning in motor behaviour science, which does not have a particular interest in the cognitive component *per se* of human behaviour, can be

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justified by practical considerations as follows: in the natural sciences like physics and biology, general theories exist which describe and explain a wide range of phenomena. Regarding piano technique, no such theory exists. A study of certain fields within psychology could provide a starting point for working towards a "method" of piano technique with at least some degree of generality. But "[e]ven within psychology, so many findings are relevant that coherence requires selectivity" (MacKay 1987:xiii). Therefore, to retain coherence within the scope of a masters thesis, the topics addressed are restricted along the lines mentioned above.

It should be emphasized that the purpose of the present study is not to prove valid or invalid any particular method from the piano methodology literature. Therefore, physiological remedies for technical problems, which abound in the literature on piano technique, are not discussed *per se*, but only when an underlying principle relevant to the motor and/or action approach can be identified from the context in which the specific author discusses that particular physiological strategy. In many cases, it will be possible to cite a great number of examples and/or opinions from the field of piano playing to illustrate a particular concept. Of these, only sufficient representative specimens to motivate the relevant issue will be retained. The same treatment holds for matters of musical interpretation.

Noting that scientifically proven data from psychology directly applicable to piano playing appears to be extremely scant, it seems that research on piano technique from a psychological perspective would to a considerable extent be restricted to an approach of, as Bruno (1985:1669-B) phrases it, "logically extrapolat[ing]" from the information available on motor control and learning, "... with concepts gleaned and correlated from ... psychology and other sciences". It is, however, imperative that great care should be taken in matters where such "logical extrapolation" seems to be required. This statement is perhaps best motivated by quoting Adams's (1987:52) view on adaptive training, a learning method which applies the techniques of individualized programmed instruction by computer directly to motor skill learning:

> Assume, for example, that a trainee is learning algebra with programmed instruction. Problems are regularly missed because he or she cannot multiply fractions. The system, detecting this shortcoming, can branch the student to exercises in fractions until a performance criterion is met, at which time the student is returned to algebra problems. *Believing that these operations should work for skills learning is thinking by analogy, which is hazardous in science.* [Italics added]

Similarly, what holds for verbal memory, for instance, cannot matter-of-factly be extrapolated to account for motor memory as well. And the various methods of piano pedagogues introduced over a period of decades, or even centuries, cannot simply be forced into some preconceived psychological mould, of which the underlying models and assumptions were conceived formally only after the

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demise of some of these pedagogues[4].

Adams's point of view stated above links closely to what Schmidt (1988b:50) terms *validity* of the measurement of motor skills, a concept which can be described as "... the extent to which the test measures what the researcher intends it to measure". This implies that conclusions drawn from an experiment measuring for instance typing speed, cannot be simply assumed to have direct bearing on piano playing as well, because the test was designed in the first instance to measure a certain variable connected with typing - not piano playing.

The present study will be carried out mainly at what can be termed the *behavioural level of analysis*; thus

> ... the primary focus is on movement behaviors that can be observed directly and on the many factors that affect the quality of these performances and the ease with which they can be learned. (Schmidt 1988b:ix)

This approach is completely appropriate for piano playing; although movements refined through practice sometimes become hardly visible, visual recordings can be used to make these movements more observable. In the traditions of cognitive psychology, however, internalized models, which describe for instance how information from the environment leads to motor responses, will be included for treatment as well, especially in the discussions involving the motor systems approach. Explorations into the specialized area of neurophysiology will generally be refrained from, except in one or two instances where circumstances warrant additional elucidation of this nature.

Finally, it is necessary to make some specific statements with respect to certain subjects the present study is *not* concerned with.

Firstly, the present study is not concerned with the development of skill in children in particular; thus the general approach should not be thought of as developmental[5]. Rather, an attempt is made to bring information to light which could be of use to any pianist who is ready to implement such information in his practising strategy.

In the second instance the study does not deal with sight-reading, aspects of which have been treated in depth by *inter alia* Fourie (1986, 1990). As far as piano technique is concerned, the learner is generally assumed to know by heart the actual sequence of notes that requires physical

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[4]It is not certain whether Bridges (1985) has refrained from this practice. In the second chapter of his thesis, entitled "Implicit psychologies of piano technique", he identifies information processing models underlying the "methods" of various pedagogues, even though such models are not even hinted at by most of these pedagogues.

[5]A developmental approach in the context of the present study would imply an emphasis on the various stages of motor skill development in *children* with respect to piano playing.

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execution; perception of the note picture in interaction with the actual execution is therefore excluded from the present thesis. Pianists are in any event almost universally required to perform from memory; it is also highly unlikely that complicated technical problems can be attempted successfully while the learner is still confined to the printed score[6].

Thirdly, although performance anxiety can seriously disrupt performance, that subject, as well as other affective factors that can influence piano playing, is not included for detailed treatment here, as performance anxiety is a field of study in its own right. Furthermore, technical problems can hardly be considered to be the domain of performers with stage fright only. Bridges (1985:5) thus aptly points out that "[t]here can be uncoordinated piano playing in happy, contented pianists just as well as nervous, diffident ones".

It should also be pointed out that, except in cases where particularly useful insights stand to be gained, results on motor control and learning pertaining to orchestral and band instruments will not be dealt with, because of the rather obvious and huge differences among the motor tasks involved. This view is supported by Handel's (1986:19) statement on the likelihood of obtaining general answers to questions on motor learning in music education: "I would suggest that general answers are unlikely because the requisite motor learning skills vary across the different kinds of music performances".

Finally, it should be pointed out that, in order to keep the number of topics discussed within manageable proportions, the subjects of *individual differences*, i.e. the "stable differences among individuals on some variable or task" (Schmidt 1988b:342) and *individual abilities* are generally not included in the present discussions.

In order to set the scene for a motor behaviour science approach to the problems of piano technique, some general issues, which are currently of interest in music education for motor learning in musical instrument performance, will be discussed in the following section.

1.5 Sidnell's issues on motor learning in music

In 1978 a paper was presented by Robert Sidnell (1986) in which some important questions with respect to motor learning in skilled musical performance were identified. Through an examination

[6]Gieseking and Leimer (1972) advocate that serious (technical) work on a piece can begin only after it has been memorized; they recommend visualization in particular to achieve this independence from the printed score.

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of these questions, an indication can be obtained of the angle motor behaviour science has to be approached from, in order to be of use in addressing the technical problems associated with the playing of musical instruments. Although Sidnell's approach to these matters shows a developmental interest, the issues he raises are nevertheless of considerable importance for the present study. It is thus appropriate to devote some special attention to some of these questions which, according to Hedden (1987:28), remain mostly unanswered:

> In 1978, Sidnell and the present author [Hedden] found it astounding that the profession had so little confirmed knowledge about an area that is such a basic part of all music education programs; in 1986, the astonishment remains.

Noting that "[t]here is no way for the interested music educator or researcher to stay abreast of all research in motor learning" (Sidnell 1986:11), Sidnell aimed with his questions to "... find those areas of research that hold specific promise for our work". Those questions which are of interest for the present study and not solely concerned with the developmental view[7] are reproduced in most instances *verbatim* below[8], while in some cases an attempt to further clarification is made by raising some more specific questions. Indications are given of whether the present study could play a role in addressing a particular question with respect to piano technique; it should however be kept in mind that the present study is not aimed in particular at resolving Sidnell's questions.

What is the relationship between motor learning and other forms of learning in music? Sidnell (1986:11) is interested here in the use of motor activities to develop sensitivity to musical stimuli, for example using big bodily movements like dancing (in children) to nurture an awareness of rhythm. It is usually intuitively assumed that an increased technical capability will provide a better opportunity for the performer's inherent ability for musical expression to be deployed to the full. But the question here goes deeper than this; as MacKenzie (1986:27) phrases it, "[i]s the motor system merely a slave for effecting a performance based on music knowledge, or is the motor system critical for the development and elaboration of music knowledge ...".

What application of current motor models should be made to music education? In Chapter 3, the two most important models of motor learning from motor systems theory, i.e. Adams' closed-loop theory and Schmidt's schema theory, are described, with in the latter case some results of attempts to apply the theory to the actual learning of music performance skills. In Chapter 2 the motor programming concept is dealt with, including some applications to certain aspects of piano playing. Whether the principles on which these theories are based are indeed valid - schema theory being highly dependent on the concept of the generalized motor program - is the question that will be

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[7]For example the development of motor skills in very young children (Sidnell 1986:11-12).

[8]For purposes of clarity, each question is italicized.

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addressed in Chapter 4, which is concerned with the action approach to motor control and learning.

Is there reason to believe motor patterns in music are different than other patterns? Sidnell (1986:13) raises the possibility that the nature of feedback[9] when learning motor responses in music may be different from the feedback received in the learning of other, non-musical motor skills:

> Since the "reals" of music are aural and perhaps less concrete, do feedback loops function differently? ... In order to establish testable hypotheses, should we apply available models or should we theorize differently?

What is the role of proprioception in small-muscle music responses? According to Schmidt (1988b:8), the term *proprioception* refers to "... the sense of body position and orientation thought to be signaled by the various muscle and joint receptors together with receptors located in the inner ear". Proprioception should be distinguished from perception in that perception deals with the environment; proprioception with the body (Gibson 1966:44). Sidnell (1986:12) notes that

> [w]e, in music education, have only a generalized knowledge about objectives of this type, and our teaching procedures are, for the most part, chosen without any understanding of this and other important phenomena in motor response.

How are the timing sequence and consideration of motor responses accomplished? What physiological mechanisms are at work? How do we make so-called automatic patterns from irregular sets of motor responses? The problem of understanding the coordination between the small limbs themselves, and between small limbs and larger limbs certainly is of a highly complicated nature. In a musical performance, the timing of muscle contractions and relaxations is also subject to the constraint posed by some external rhythmic requirement, i.e. that of the piece of music that has to be performed. While the present study is not aimed at a detailed understanding of physiological and neurological factors underlying motor behaviour, a theory of timing and rhythm in skilled piano performance - also applicable to other skilled performances - based on motor systems theory principles as proposed by Shaffer (1981, 1982, 1984), is discussed in the present study (see Chapter 2).

What can we learn about efficient motor practice? Sidnell (1989:12) here raises questions concerning *inter alia* practice lengths, rest between practice, and the effects of fatigue; these questions will be discussed in Chapter 5.

What is the transferability of motor skills? According to Sidnell (1986:12), it is common practice among pianists

> ... to develop high levels of technique on the assumption that there will be application to a

[9]The subject of feedback will be given some detailed treatment in Chapter 3.

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> whole population of motor performance problems. ... Yet one can document countless hours in performance training where lack of pattern recognition retards the accomplishment of an accurate, complete motor response.

Some discussion will be devoted in Chapter 5 to the subject of transfer in general motor tasks, and possible applications to piano technique will be pointed out.

How does motor memory function? Most pianists have probably experienced that motor memory at times appears to function in a manner unconnected to any cognitive awareness. Although relatively little information on motor memory and retention has emerged from research on this topic in general, some discussion is devoted to it in Chapter 3 in the context of the motor systems perspective.

1.6 Overview of the thesis

Chapter 2 deals with the motor systems approach to motor control, with special reference to piano technique.

The concepts of movement and motor control will be defined. Piano technique will be classified in terms of the continuous/discrete/serial and the open/closed dimensions of motor behaviour.

In order to establish a foundation for a true understanding of theories of motor control in the context of the experiments from which they have evolved, two approaches to the quantification and qualification of movements will be described, namely the measurement of movement characteristics and movement outcome respectively. In order to render these rather general concepts more specific, a typical procedure for measuring aspects of movement outcome in piano playing will be reproduced.

Three presumed stages of information-processing in humans will be described, namely stimulus-identification, response-selection, and response-programming. The conceptual distinction, as well as its merits, between three structures for motor memory, i.e. the short-term sensory store, short-term memory, and long-term memory will briefly be looked into.

The current view that the concept of attention should be defined in terms of the interference between motor tasks will be explained. The earlier fix-capacity and the more recent pools-of-resources theories of attention will be described briefly. The influence of interference on attention during and after the three information-processing stages will be pointed out. The concept of automaticity between tasks will be defined, and the validity of the idea of controlled processing evolving through practice into automatic processing will be subjected to closer scrutiny.

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In an attempt to make the theorizing about information-processing more relevant to the problems of motor skill execution in everyday life (including piano playing), the influence on information-processing of spatial and temporal anticipation will be considered. So will be, for the sake of completeness, the influence of stress and arousal on information-processing, with regard to which some subtleties will be pointed out.

The analogy of man as a computer prevalent among motor systems theorists will be investigated, and three mechanisms for motor control will be described, namely the closed-loop system, open-loop system, and feedforward control. The concept of a motor program will be defined, and some arguments will be presented to show where the concept originated from. The role of feedback during the execution of motor programs will be pointed out. The generalized motor program will be introduced as an improvement on the original concept. Certain problems of coordination in piano playing will be looked into and explained using motor programming notions. A motor programming basis for rhythm and timing in piano performance will be presented.

Reservations action theorists have with respect to the motor systems approach to motor control and learning will be dealt with.

Finally, a summary of and conclusions on the most important findings of the chapter will be presented.

Chapter 3 deals with the motor systems approach to motor learning, with special reference to piano playing.

The concepts of motor skill, motor learning and motor transfer will be discussed. The relative importance of three types of intrinsic feedback for piano playing will be examined; descriptions will be given of how aural, kinesthetic and visual feedback can be employed by the pianist. Knowledge of results and knowledge of performance will be singled out for discussion as particularly important modes of extrinsic feedback. The question on when knowledge of results should be given to the learner will be addressed, as well as the significance of kinematic and kinetic feedback and videotape replays as methods of giving knowledge of performance to the learner of piano playing.

The stages of motor learning will be identified. Two important motor learning theories will be discussed, namely Adams's closed-loop theory, and Schmidt's schema theory. Each model's representation of how learning takes place will be described. Logical inconsistencies and limitations of each theory will be discussed. Schmidt's theory was introduced to eliminate certain short-comings in Adams's theory; the nature of these improvements will be investigated. Strategies will be

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identified for the practical application of concepts from schema theory to establish more effective musical instrument practice; some research findings to determine whether such strategies indeed lead to improvements in motor learning in music will be examined.

The subject of motor memory and retention will be looked into. Some possible theories of forgetting will be pointed out, and the relevance of the concepts of short-term and long-term memory will be examined. The significance of the phenomenon of warm-up decrement for piano playing will also be investigated.

Some conclusions will be made, and the most important findings summarized, in the final section.

In Chapter 4 an action systems view to motor control and learning is presented, with, where applicable, reference to the problems of piano playing.

The action systems approach to motor control as opposed to the motor systems approach will be briefly outlined. The distinction between functionally-defined actions and the traditional motor systems understanding of movements will be pointed out. Postures and movements as the subsidiary components of any action will be described; the piano playing method of Taylor employing the so-called expanding posture as the principal catalyst for piano technique, and possible common denominators between this method and action systems theory, will be investigated. Postural precedence effects will be discussed.

The way in which action systems and action cycles comprise human motor behaviour will be looked into; basic actions will be defined. Reasons will be investigated for action theorists regarding the phenomenon of tool use as an important questioning factor of motor systems premises; various examples will be cited from the literature on piano methodology to prove the notion that the hand is often seen as a tool in piano playing. The question of whether the dynamical systems approach presents a viable alternative to the motor programming idea of motor systems theorists will be investigated.

The ecological perspective advocated by Gibson on how humans obtain up information from the environment will be examined in broad terms. To avoid confusion, certain aspects of the relevant terminology will be clarified. The perceptual systems that appear to have relevance for piano playing will be looked into briefly.

Indications in the literature on piano methodology, that piano playing may be a goal-directed activity in the action sense, will be looked into. Emphasis will be placed on musical aesthetics as the

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"goal", in relation to technique. Common denominators between Abby Whiteside's apparently functionally-orientated concept of technique and action systems theory will be investigated and commented upon.[10]

One or two action systems ideas on motor learning will be pointed out. Some remarks will be made on whether action systems theory indeed can account for motor learning in humans.

The chapter will be concluded with a summary of the most important findings, and some conclusions pertaining to these findings.

In Chapter 5 an investigation will be launched into how the different variables involved in motor skill practice are influenced by, and can be organized according to, the premises derived in earlier chapters from either the motor systems view and/or the action systems view on motor control and learning. Factors that may not directly pertain to earlier concepts, but are as important for practice, will be pointed out and briefly described for the purposes of forming a more complete picture of motor skill practice. Where appropriate, suggestions for piano practice in particular will be included.

Firstly, certain prepractice conditions that could enhance motor learning will be described. The roles of verbalized instruction, observational learning, verbal pretraining, knowledge of scientific principles and establishing a reference of correctness before practice begins as methods for developing a concept of the task will be examined. Some significant points on motivation will be discussed discussed.

The structuring of the practice session will be discussed with respect to variables that will include the number of practice trials, massed vs. distributed practice, the time involved in massed practice, variability in practice, and the importance for conditions of practice to resemble the conditions of the actual performance of the skill. Regarding piano playing, special attention will be given to the questions of practising rapid passages slowly, and practising problematic passages in varied rhythmical patterns.

The conditions under which maximum transfer from practising the task to its actual execution occurs will be subjected to scrutiny. Some fundamental principles of motor transfer will be pointed out. The question of practising a piece at the piano in parts vs. practising the whole will be looked into.

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[10]It is by no means suggested that the methods of Whiteside and Taylor, which are singled out for discussion in Chapter 4, are the *only* methods in the piano methodology literature displaying factors in common with action theory concepts. Rather, these methods were selected because they are documented fairly extensively, and appear to have been tested in practical teaching situations.

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Some comments will be made on mental practice, which is often used by pianists, and the subject of guidance in piano playing.

Finally, conclusions will be reached on *inter alia* the ability and usefulness of the motor systems approach vs. that of the action systems approach to supply guidelines in terms of motor control and learning for structuring practice. Some of the most important findings will be summarized as well.

The present study will be rounded off with some final conclusions and recommendations in Chapter 6, based on the material presented in previous chapters.

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CHAPTER 2

THE MOTOR SYSTEMS APPROACH TO MOTOR CONTROL WITH SPECIAL REFERENCE TO PIANO TECHNIQUE

2.1 Introduction

2.1.1 The concept of movement

Schmidt (1988b:17) defines[1] *movement* of humans and animals as "[c]hanges in joint angles, the position of the entire body, or both ..."[2]. Movements can be divided into two categories: those that are "primarily genetically defined", i.e. inherited, and those that are learned through considerable practice and/or experience (Schmidt 1988b:3). The latter type of movements is referred to as motor skills[3]. Piano technique can be considered a compendium of highly-evolved motor skills; it is also sometimes referred to in the methodological literature on piano playing in the singular as *a* skill.

2.1.2 The study area of motor control

Motor control is defined by Schmidt (1988b:17) as that "... area of study dealing with the understanding of the neural, physical, and behavioral aspects of movement", while the interrelated field of *motor behaviour* can be considered "[a]n area of study stressing primarily the principles of human skilled movement generated at a behavioral level of analysis".

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[1]This definition will be somewhat extended, as well as critically reconsidered in Chapter 4, which deals with the action approach to motor control.

[2]A *joint* is "a point of contact between 2 or more bones of an animal skeleton together with the parts that surround and support it" (The Penguin English dictionary 1985:451).

[3]Since skilled motor behaviour usually implies that motor learning has taken place, the term *motor skill* will be defined in more formal terms under the heading of motor learning, i.e. in Section 3.1.1.1 in particular.

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In the 1970's, motor behaviour research strongly tended toward the field of cognitive psychology in reaction to the oversimplified stimulus-response (S-R) theories of movement prevalent before. The influence of cognitive psychology manifested itself in the relinquishing of a *task orientation* to movement research, "... which focuses primarily on the effects of variables on the performance of certain motor tasks", for a *process orientation*, "... which focuses on the underlying mental or neural events that support or produce movements" (Schmidt 1988b:14).

Sidnell (1986:10) points out that, for the purposes of the music educator or musician wanting to learn more about motor problems pertaining to musical performance through studying paradigms[4] investigated in the psychological literature, the latter paradigms usually being unrelated to music, "[t]here is much research in motor learning and behavior - in fact, too much". In this chapter[5], therefore, the inevitable inclusion of certain subjects and the exclusion of others have been guided by Schmidt's (1988b) proportional distribution of attention to significant, and less significant, information. Furthermore, the approach is, as phrased by Adams (1987:41), "... unashamedly behavioral"; while, as noted in Section 1.4, the emphasis here is not on the intricate workings of the central nervous system or the physiology of movement, the occasional reference will be made to these matters for the purposes of elucidation, when deemed necessary.

2.1.3 Classification of motor behaviour

Two reasons can be stated (Schmidt 1988b:45) for the necessity of employing classification systems of motor responses (or motor skills) when applying scientific method to the study of motor behaviour, the first of which is to facilitate communication within the scientific community. The second reason is that the laws of movement behaviour are not independent of the kind of motor task that is performed - " ... the relationship between certain independent and dependent variables is often different for one kind of task or behavior as compared to another".

Schmidt (1988b:45) singles out two important classification schemes for motor responses, namely

- the continuous/discrete/serial dimension
- the open/closed dimension

[4]A paradigm, or law, is "... [a] statement of a stable dependency between an independent variable and a dependent variable" (Schmidt 1988b:41).

[5]As well as Chapter 3, which deals with motor learning as seen by the motor systems approach.

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2.1.3.1 The continuous/discrete/serial dimension

Discrete movements have a recognizable beginning and end - examples of discrete movement tasks with different temporal lengths, which are generally very short, are throwing, pressing a key on the keyboard, or signing one's name.

Continuous movements, on the other hand, are defined as having no recognizable beginning and end. Execution continues more or less uninterrupted until the response is arbitrarily stopped (Schmidt 1988b:46). Examples of continuous movements are swimming, jogging and tracking tasks. Tracking tasks[6], which can be considered a common kind of skill which is often tested in the laboratory, are described by Schmidt as follows: "[the tracking task] ... is characterized by a pathway (track) that the individual is to follow and some device that the individual attempts to make follow the track via certain limb movements". In driving a car, for instance, the road is the track and the car the device that is to follow the track.

Finally, *serial movements* are neither discrete nor continuous, but should rather be considered as consisting of a series of discrete movements strung together. Examples of serial movements are starting a car, and some tasks on production lines in industry (Schmidt 1988b:47).

It appears as if piano playing can be regarded, due to its complexity, as a kind of movement task that displays both serial and continuous characteristics. Seen as a serial task, depressing of the various keys or simultaneous depressing of groups of keys can be considered the constituent series of movement elements. Its continuous facet is perhaps most clearly displayed through the fact that action continues uninterrupted once a piece is embarked upon. Especially high speed, *perpetuo moto* type figures, alike to for instance the quasi-arpeggiated accompaniment found in Chopin's *Etude* Op. 25 No. 2 which is sustained throughout the whole piece, would intuitively seem to be a performance task of a continuous nature, rather than a series of discrete movements - pressing the individual keys comprising the notes of the accompaniment - strung together.

2.1.3.2 The open/closed dimension

An alternative method for classifying movement skills is through observing environmental predictability. *Open skills*, for example boxing, are skills "... for which the environment is constantly (perhaps unpredictably) changing, so that the performer can not effectively plan the response", while

[6]The description of tracking tasks is included here in order to clarify further references that are made in this thesis to experiments involving tracking.

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closed skills are those skills for which the state of the environment can indeed be predicted (Schmidt 1988b:47). Included among the latter type are those skills that are executed in a variable environment, but where the changes are essentially predictable. Somewhere between open and closed skills exists a class of skills with environments that can be considered semi-predictable (Schmidt 1988b:48).

The usefulness of any attempt to classify skills according to their open and/or closed characteristics becomes apparent when the following three questions posed by Schmidt (1988b:48) are considered:

1. Should open and closed skills be taught differently?
2. Do different individuals perform better in either the one or the other?
3. Do closed and open skills have different laws of performance?

While superficial considerations could lead the observer to regard piano playing as unequivocally closed (the positions of keys and the sizes of keys are the same on all pianos), when "trying out" different pianos some differences can indeed be observed, not the least of which is the fact that the heaviness of touch on all pianos is different. Furthermore, the acoustics of the room in which the piano stands as well as the presence or absence of an audience - and its degree of quietness - can have a marked effect on the quality of aural feedback that is available to the performer. In particular, the performer may not be able to hear himself properly, or the sounds that he produces "sound differently" in the immediate vicinity of the instrument than some distance away from it. A common complaint among pianists is the fact that different sections of the keyboard range may differ in volume strength; thus the bass may be predominant on a certain piano, while the top notes could stand out excessively on another. Even pedal actions are often found to differ among pianos. At a more sublime level, pianos also differ considerably with respect to the variety of tone colours that can be obtained by the accomplished pianist. It is therefore not surprising that Stangeland (1981:33) regards the success of any performance as greatly dependent on the instrument at the disposal of the pianist:

> Even an exemplary re-creation of the composer's score on the part of the pianist can be ruined if the instrument is inadequate; worse yet, it is unlikely that the pianist can achieve anything approaching an exemplary performance on such an instrument, no matter how thorough the preparation or how inspired the pianist may be.

From the former arguments it is clear that piano playing can be associated with a semi-predictable environment, a viewpoint which is shared by Bridges (1985:85). But whether piano playing is regarded as a closed or semi-closed skill will depend on the nature of the learner's involvement with music. For the person who plays at home for his own enjoyment, piano playing is a closed skill. For the concert pianist, who almost daily is required to adjust to different pianos, piano playing is a semi-closed skill. The term semi-closed, rather than semi-open, is used to indicate that piano

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playing is predominantly closed; even if an unknown instrument is to be used, most performers should be able to familiarize themselves within a relatively short period beforehand (or even during the first piece on the recital program) with the instrument's touch, sound quality, and also the most obvious of its fallacies. After becoming acquainted with the instrument in this manner, the pianist's environment is not nearly as unpredictable as the environment normally associated with open skills, such as fencing.

The question arises whether piano technique is indeed instructed with the semi-closed nature of piano playing accounted for; apparently this is not the case. More research is needed to determine the nature such instruction should take on.

2.2 The measurement of movements

In order to place theories of and experiments on motor control in the proper perspective, it is necessary to have some idea of how the characteristics of movements are quantified and/or qualified, i.e. measured. This principle is expounded on by Schmidt (1988b:19) as follows:

> ... to truly understand the principles of motor control and learning, it is essential to know where the research results come from, how they were achieved, what the limitations were on the techniques used to generate them, and how generalizable these results are to other situations.

According to Schmidt (1988b:50-51), the measurement of movements can be approached in two different ways, namely

- measurement of the characteristics of the movement *per se*
- measurement of the degree of success in achieving the goal the movement was originally intended for

In the following sections, these approaches will be described more fully.

2.2.1 Describing movement characteristics

Characteristics of simple movements are very often described through the use of a set of measurement techniques termed *kinematics*, which can be described as (Schmidt 1988b:51)

> ... the description of "pure" motion, without regard for the forces and masses that are involved. As applied to movement behavior ... kinematic measures are those that describe the movement of the limbs and/or the entire body.

There are obviously many different variables that can be recorded for describing movements - Schmidt points out *inter alia* the respective locations of the various limbs involved in the movement, angles of the joints and the time relation between the movement in one joint and the

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movement in another. Devices that are used in the laboratory to gather this data are described by Schmidt (1988b:51-55)[7]; these include electromyographic (EMG) recordings of electrical activity from muscles involved in executing the movements under consideration.

Biomechanical motion analysis techniques were used by McArthur (1988:1692-A) to investigate certain movement patterns in the execution of an elementary piano piece; while an awareness of the use of such methods in the study of piano playing is certainly desirable, a detailed discussion of these techniques is not of particular interest for the purposes of the present study.

2.2.2 Describing movement outcome

Generally, assessment of movement outcome has bearing on the movement in relation to an object or another performer in the environment (Schmidt 1988b:56). Movements do however exist for which the relationship with the environment is not that directly observable, for instance dancing, or mannerisms in piano playing. The achievement of movement goals can be evaluated in terms of three fundamental variables, namely

- error
- speed
- response magnitude

In subsequent sections these variables will be discussed in greater detail.

2.2.2.1 Measures of error

Errors in movement can be expressed in terms of certain mathematical quantities. Some important error measures are (Schmidt 1988b:56-60,72)

> ... *constant error* (a measure of average error or bias), *variable error* (a measure of consistency), *total variability* (a measure of overall error), and *absolute error* (also a measure of overall error).

2.2.2.2 Measures of speed

Measures of *speed* are used "... when accuracy is less important and when rapid actions are critical" (Schmidt 1988b:72). Important indicators of movement speed are *reaction time* (RT)[8] and *movement time* (MT).

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[7]These laboratory techniques *per se* are not of immediate relevance for the present study.

[8]Reaction time is also an extremely valuable indicator in the study of human information-processing, as will be pointed out in Section 2.3.

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Reaction time is defined by Schmidt (1988b:64) as "... a measure of the time from the arrival of a suddenly presented and unanticipated signal to the *beginning* of the response to it". The temporal location of the RT in the so-called *reaction time paradigm* is shown in Figure 2.1[9]. In the discussions by some authors, the division of RT into its *central*, i.e. decision, and *peripheral*, i.e. musculature, components is employed. Associated with the central component is the *premotor RT* and with the peripheral component the *motor RT* of the movement. *Premotor RT* is defined as (Schmidt 1988b:64) "... the interval from the signal to the first change in EMG ... [It] is thought to represent central process (e.g., perception, decisions)".[10] The presence of a premotor RT indicates that the command to move the muscle has not yet reached the muscle. The *motor RT* of the movement represents processes in the muscle itself; it can be considered an indication of the time from the appearance of electrical activity in the muscle to the actual, observable occurrence of the response; Kerr (1982:218) describes it as "... the interval between the arrival of ... [the] neural signal at the muscle and the actual contraction of the muscle that initiates the response or the first observable movement".

Movement time (as diagrammatically explained in Figure 2.1) is defined as (Schmidt 1988b:65) "... the interval from the initiation of the response (the end of RT) to the completion of the movement".

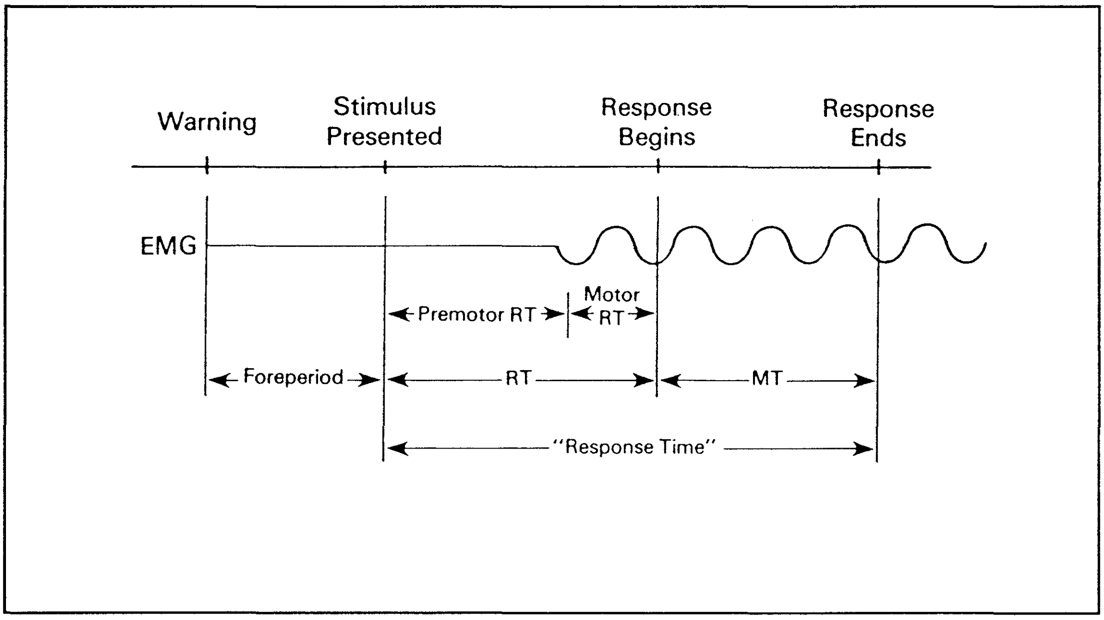

Figure 2.1 Critical motor events recorded in the reaction time (RT) paradigm (from Schmidt 1988b:65). The upper trace is a hypothetical representation of the electrical activity in the muscle relevant for the movement.

[9]As reproduced from Schmidt (1988b:65).

[10]Apparently, motor behaviour science under the motor systems approach is not particularly interested in the subject of perception. This, however, appears not to be the case for the action systems approach; definitions and discussions of perception and associated topics like sensation will thus be reserved for the relevant chapter, i.e. Section 4.2.8 in particular.

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A question that often emerges in the study of movements when movement times decrease is that of the influence of the so-called *speed-accuracy trade-off*, which holds that (Schmidt 1988b:65)

> ... when performers attempt to do something more quickly, they typically do it less accurately. In most measures of speed, therefore, accuracy requirements are kept to a minimum so that speeding up the response (which is the major goal for the subject) does not seriously affect accuracy.

It is rather obvious that experiments requiring high speed but low accuracy would be of little significance for the field of piano technique, since speed and accuracy are inextricably intertwined in the performance of virtuoso passages.

2.2.2.3 Measures of response magnitude

The third way a skill can be measured is through determining the *response magnitude*; in the case of for instance, a javelin thrower, the response magnitude would be the distance the javelin has travelled. In the case of piano playing, a (rather crude) measure of the response magnitude could be the loudness produced by the individual keys struck by the performer.

According to Schmidt (1988b:66), response magnitude as a measure of skilled movement is, rather surprisingly, not used much in motor behaviour research, "... as the scientists apparently believe that skills are more easily assessed by measures of accuracy or speed".

2.2.2.4 Measuring speed and response magnitude in piano playing

In this section, an experimental setup is described which was employed by Shaffer (1981) for indirectly measuring various manifestations of speed and response magnitude in piano playing through detecting and coding the associated movements in the piano action. As a first step, Shaffer's (1981:343) succinct but exceptionally clear explanation of the functioning of the piano action is reproduced, *verbatim*, below:

> In the piano action, when a key is struck it raises a damper off its string and actuates a hammer, throwing it against the string and causing this to vibrate. The force of keystroke is translated into speed of hammer movement and thus into sound intensity. On the rebound the hammer is caught midway in its return trajectory; when the key is released the damper falls back onto the string, stopping the sound, and the hammer falls to its resting position. There are two foot pedals: pressing the left pedal displaces the keyboard action so that the hammers strike one less string on multistring notes, producing a quieter sound; pressing the right pedal lifts all the dampers off their strings, so that a note can be sustained when the key is released and other strings can vibrate in sympathy.

Using electronic transducers and a computer, Shaffer (1981:343) proceeded as follows to obtain and process information on the piano action as representative of the performance:

> The photocells were mounted in pairs, one pair for each of the 88 keys. These cells

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detected the transits of a hammer shank in its up and down trajectories. They were placed to detect the (approximate) moment a key was struck, the moment the hammer hit the string, and the moment the key was released. Two microswitches detected the operation of the foot pedals. The signals from these sensors were amplified and coded into 12-bit words by a strobe circuit that fed them to a laboratory computer. All such words were assigned clock times to the nearest microsecond by the computer clock and stored on tape.

Following a performance the sequence of words was translated into a list, showing for each note played its time of onset (obtained from the upper cell), its time of offset (obtained from the lower cell), and the time difference between cells in the upward transit of the hammer. This listing was annotated by hand and returned to the computer, which then compiled a musically more interesting listing of the performance.

The new listing displayed the performance in successive bars of the music and separated the different voices. It listed for each note played its duration, the time between sounding that note and the next one in the same voice; its tonal quality of legato or staccato, measured by its temporal overlap, positive or negative, with the next note in its voice; and an index of its intensity, taken as the inverse of the upward transit time of the hammer. This index, monotonic with both the force of striking and the intensity of sound produced, was a consistent index of the former across all keys, but not of the latter across all notes, since this was a complex function of the acoustic properties of the piano and the room.

2.3 Information-processing theory and memory systems

Information is defined by Kerr (1982:309) as "the psychological concept of stimuli and cues. A stimulus can be almost any item present in the environment".[11] Defined more accurately from the engineering viewpoint concerned with information-processing, information can be described according to Schmidt (1988b:98,83) as

> ... [t]he content of a message that serves to reduce uncertainty. ... The amount of information transmitted is affected by both (a) the amount of uncertainty prior to the signal's being presented and (b) the amount of reduction of uncertainty.

For the purposes of the present study the first definition will suffice; thus it is not required to examine the statistical implications implicit to the second definition in greater detail.

Information theory, which is concerned "... with the balance between uncertainty and information" (Kerr 1982:37), is based mainly on developments in the field of communications engineering, in particular the work done by Shannon and Weaver in the late 1940's. About a decade later the first attempts were made to apply these concepts to the field of motor control.

Human movement in the environment can be studied from the perspective of man as a processor of the information that is available in the environment. It is postulated that the individual accepts

[11]The notion held by some ecological psychologists on what a stimulus is, is not quite this simple, as will be pointed out in Section 4.2.8.1.

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information into storage systems called *memory*, that the information is subject to *processing* and that information is output to the environment in the form of movements (Schmidt 1988b:97). It is in fact possible to visualize a human as analogous to a so-called *black box* with input a signal from the environment and output a certain motor response. The events and processes that occur *within* the black box in particular are of interest for cognitive psychology. Knowledge of these processes "... is inferred from the overt behavior of the human under various experimental conditions" (Schmidt 1988b:75); direct investigations into the nature of the internal processes is not possible "... because the neural processes and their locations in the brain are not well understood" (Schmidt 1988b:76).

2.3.1 The stages of information-processing

Perhaps the most common method for inferring knowledge of human information-processing capabilities from observable motor behaviour is through observation of temporal aspects of the performance; in this regard the so-called *chronometric approach*

> ... makes heavy use of the reaction-time (RT) method, whereby the chief measure of the subject's behavior is the interval between the presentation of a stimulus and the beginning of the response (i.e., RT). (Schmidt 1988b:76)

Schmidt (1988b:77-78) gives the following typical interpretation of an everyday motor skill along the lines of the chronometric approach to the study of human information-processing:

> ... assume in driving a car that stimuli from the environment (vision of the road, horns honking) and from the driver's body (acceleration, vibrations) enter the information-processing system as input ... . As each stimulus is input, it is processed, leading to a response or not. Thus, the driver can be thought of as an information-processing channel,to which information is continually presented, and out of which comes responses.

Implicit in the above is the assumption that processes within the individual when driving a car - or throwing a ball and playing a succession of chords on the piano, for that matter - and performing a RT task are the same. Schmidt (1988b:78) warns that "... this assumption could be wrong, and many [authors] ... think that it is."

Following the work by Donders of 1868-1869, Schmidt (1988b:77) identifies three general stages of information-processing[12], namely

- stimulus-identification
- response-selection
- response-programming

All three stages of information-processing occur during RT.

[12]It is of course highly likely that each stage itself consists of various subsidiary stages.

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In the following sections these stages of information-processing will be examined more closely.

2.3.1.1 The stimulus-identification stage

Stimuli impinge on the performer of motor skills through the sense organs. In piano playing, the classic example of stimuli presented to the performer is the printed music in front of him[13]. Bridges (1985:11) notes that in memorized music this visual information is stored in a transformed form as "... an aural, kinesthetic, and/or emotional concept". Probably of even more importance than visual stimuli in playing from memory at a stage when some fluency has been achieved are aural and kinesthetic stimuli[14], while the reverse situation may be the case when movements are learned from grassroots level, requiring for instance the wrist to be carefully watched in the study of arpeggio playing. In the present study, the stimulus-identification phase will be thought of as beginning with a stimulus in the environment that must be detected, i.e. the stimulus is starting the chain of events. This assumption is arbitrary, of course, since the stimulus could just as well be the result of the human interacting with the environment; in piano playing the stimulus, for instance a sound at a certain level of intensity, can be the result of a previous movement, but also be the stimulus for the next movement. Schmidt (1988b:97) depicts *stimulus-identification* as

> ... concerned with the reception of a stimulus, preliminary preconscious analyses of features, and extraction of patterns from the stimulus array. Variables like stimulus clarity and stimulus intensity affect the duration of processing in this stage.

Two components are associated with the stimulus-identification phase, namely *stimulus detection* and *pattern recognition*.

(a) Stimulus detection

When a stimulus acts on an individual, it must first of all be detected. The stimulus must be "... transformed into the code of neurological impulses headed towards the brain" (Schmidt 1988b:78), and it is assumed that the stimulus is further processed at various levels of analysis until it, as Schmidt puts it, "... *contacts memory*", arousing the proper association in memory. This association may be its name, its colour, or in the case of piano playing, for instance the relative intensity and/or pitch of an aural stimulus. The factors mentioned above in the description of the stimulus-identification stage that influence the temporal duration of the stage also effects the stimulus

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[13]It has been mentioned before that the present study is not aimed at an investigation of the complex processes involved in sight-reading; it is rather assumed that the note sequence is memorized already, and that the problem facing the learner is the physical execution of this note sequence.

[14]The manner in which these stimuli function as feedback in the learning process is examined more fully in Sections 3.2.1.1 and 3.2.1.2.

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arousing the right association rather than the wrong association, or all possible associations.

(b) Pattern recognition

The need for pattern recognition arises from the fact that stimuli seldom occur in an isolated fashion; thus it becomes necessary to extract a pattern from the stimuli presented. The recognition of patterns can be either an inherited or learned ability; the former would for instance apply to verticality (Schmidt 1988b:78), while the latter would for instance pertain to recognize the movements required for fluent scale playing at the piano.

While the importance of analyzing patterns from static visual stimuli has been stressed by the Gestalt theorists[15], according to Schmidt (1988b:79), "... even more important for an understanding of motor behavior is an ability to extract patterns of movement from the environment". Patterns of the movements from one's own body can be inferred from how the environment changes from moment to moment, as well as from receptors in limbs, muscles, eyes and the inner ear (the latter functions with regard to balance). In fast-action sports, a judicious analysis of movement patterns can lead to an accurate prediction of what the opponent's next move will be (Schmidt 1988b:80).

As for piano playing, inferring information from the environment would be rather difficult, as the only changes that occur are the downward displacements of keys through relatively minute distances. Patterns learned through careful observation of one's own successful and less successful attempts, could however be of some use. Such observational activities are usually regarded, in the learning situation, as visual feedback; the use of visual feedback in the development of piano-technical skills will be examined more fully in Section 3.2.1.3. The advantages and limitations of observational learning, where the idea is to learn through studying *another* person's movement patterns, will be addressed in Section 5.2.2.2.

2.3.1.2 The response-selection stage

The information-processing stage of *response-selection* is described by Schmidt (1988b:97) as

> ... concerned with the translation or decision mechanisms that lead to the choice of response. The duration of this stage is sensitive to variables such as the number of stimulus-response alternatives and S-R compatibility (the extent to which the stimulus and response are "naturally" linked).

Of special interest for the duration of the response-selection stage is the number of movement

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[15]See for example Bower and Hilgard (1981).

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options available to the performer. An important parameter in this regard is the *choice reaction time*, or choice RT, which is defined by Schmidt (1988b:97) as the "RT for a task in which each response to be made is associated with a different stimulus".

It has been believed for over a century that information-processing involving the selection of a response from a number of alternative responses takes longer when the number of alternatives are larger (Schmidt 1988b:80), consequently leading to a longer time period for the actual response to take place; thus, "... if increasing the number of alternatives causes an increase in the choice RT, then the increased RT is associated with changes in the way the response-selection stage processed the information".

A relationship was discovered by Hick and Hyman in the early 1950's between the number of stimulus alternatives and choice RT; this relationship is referred to as Hick's law, or sometimes the Hick-Hyman law, for example Kerr (1982:220). This law, expressed in mathematical terms, states that (Schmidt 1988b:98) "... the choice RT is linearly related to the Log_2 of the number of stimulus-response alternatives, or to the amount of information that must be processed in order to respond".[16] Thus a particularly attractive interpretation, due to its simplicity, of Hick's law is that the time necessary for deciding on a response is linearly proportional to the "... amount of information that must be processed in coming to that decision" (Schmidt 1988b:82). It is however possible that the validity of this law under particular circumstances can be affected by "... high stimulus-response compatibility, extensive practice, or repeated responses" (Kerr 1982:255).

2.3.1.3 The response-programming stage

Schmidt (1988b:97) defines *response-programming*, the final stage in the series of three stages that comprise information-processing, as concerned with preparing the movement decided upon, or "... changing the abstract idea of a response into muscular action. The duration of this stage is related to variables affecting the response, such as response complexity and response duration". The complex series of events that occur in the response-programming stage is postulated by Schmidt (1988b:89) as the recall of some "program of action" from the memory of the performer, preparation of the program to get started, preparing relevant subsystems of the motor system for execution of the program, and initiation of the movement. The subject of motor programming will be addressed in Section 2.8.

[16] $\text{Log}_2(N)$ is the power to which the base 2 must be raised to achieve N.

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2.3.2 Memory systems

Schmidt (1988b:91), following an analogy with computer memory systems, points out three conceptual structures that hold information for future processing, namely

- short-term sensory store (STSS)
- short-term memory (STM)
- long-term memory (LTM)

Adams (1987:64), however, points out that while the differentiation between short-term and long-term memory systems was viable for verbal retention and researchers hoped that motor retention[17] could be described in the same way, it became clear by the 1970's

> ... that the conceptual distinction between short- and long-term memory had little to offer an understanding of motor behavior. Research on motor retention became more of an empirical undertaking, with efforts aimed mostly at short-term motor retention ...

For the present discussion on motor *control*, and in view of Adams's notion on the validity of a conceptual division into types of motor memory, it is sufficient to consider here for the sake of completeness merely brief descriptions of the three conceptual structures for motor memory. Some additional remarks on STM and LTM will be made in the part of the present study dealing with motor learning as viewed from the motor systems perspective, i.e. in Section 3.5 in particular.

Schmidt (1988b:98) defines the *short-term sensory store* (STSS) as "[a] functionally limitless memory store for holding literal information for only about 1 sec". STSS is thought to be the memory level nearest to the environment, accepting information presented by the environment and losing it again as soon as new information presents itself. *Short-term memory* (STM), which is usually closely associated with consciousness[18], is described by Schmidt as "[a] memory store with a capacity of about seven elements, capable of holding moderately abstract information for up to 30 sec." STM is regarded as storage system for information from either STSS or LTM; evidence was found by Miller (1956) that verbal STM has a capacity of only seven plus or minus two items or chunks; the latter being larger, recognizable collections for smaller items, for instance words[19]. In some unknown way, information is transferred from STM to *long-term memory* (LTM), which can be described as "[a] functionally limitless memory store for abstractly coded information, facts, concepts, and relationships; presumably storage for movement programs".

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[17]*Motor retention* will be defined in more formal terms in Section 3.5.

[18]The problems surrounding the concept of consciousness will be remarked upon briefly in Section 2.4.

[19]The concept of chunking is discussed with respect to piano sight-reading by Fourie (1990), and with respect to facilitating the execution of technically difficult passages by Jacobs (1990).

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2.4 Attention

2.4.1 The concepts of attention and interference

Although an active interest has been maintained for many years by psychologists and motor behaviour researchers regarding the subject of attention, it is still not clear how attention should be defined. While motor behaviour science is not concerned with addressing the role of the conscious mind in motor activity in particular[20] (Bridges 1985:15), attention has in the past been closely associated with the concept of *consciousness*, or (Schmidt 1988b:139) "[t]he mechanism or process by which humans are aware of sensations, elements in memory, or internal events". Common sense views of consciousness have contended that it controls what humans perceive and how they act; it has however been extremely difficult to attempt verification of these and other views because

> ... the only way to understand what was "in" subjects' consciousness was to ask them to *introspect*, or "search their own minds", which is acknowledged to be prone to errors or biases related to situational variables and expectations.[21] (Schmidt 1988b:100)

Schmidt (1988b:100), however, declares that the relationship between attention and consciousness is of a rather superficial nature and thus does not warrant further exploration; the focus should rather be aimed in terms of the human's limited capacity for handling information from the environment or from long-term memory. While some theorists think of attention as a single limited capacity for information-processing, others hold the view that attention

> ... is really a number of pools of capacity for separate kinds of processing. The capabilities to perform various tasks together is presumably limited by these capacities; therefore, attention demand is usually estimated indirectly by the extent to which tasks interfere with each other. (Schmidt 1988b:138)

The phenomenon of interference among tasks, is of considerable importance both for attention and learning, or "automatization", of motor tasks. Schmidt (1988b:101,139) distinguishes between *structural interference* and *capacity interference*; the former is "[i]nterference among tasks caused by the simultaneous use of the same receptors, effectors, or processing systems", while the latter can be described as "[i]nterference between tasks caused by limitations in attention". An example of

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[20]An approach that is followed in the present study as well, noting its motor behaviour emphasis. A possible foundation for attacking this problem could be found in the so-called psychologies of consciousness, which is explored by Bridges (1985).

[21]In view of this uncertainty about what consciousness actually is, it is not clear on what grounds Bridges (1985) identifies a boundary between the conscious and unconscious - or "Province of Automaticity" as he describes it using Matthay's terminology (Bridges 1985:34) - in piano playing. This boundary plays a major role in the various "implicit psychologies of technique" identified by him in the methods of *inter alia* Matthay, Gát, and Whiteside, as can be easily seen in his information-processing flowchart representations of each method (Bridges 1985:36,47,62).

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structural interference is writing and dialling the telephone with the same hand because the hand can only be in one place at a time.

Interference can serve as an indication of whether a task requires attention as follows (Schmidt 1988b:100): if two tasks can be performed as well at the same time as when each is performed on its own, one of the tasks is said to be performed "automatically", thus not demanding part of the limited capacity for attention. If, however, a certain task is performed less well when carried out simultaneously with another, both tasks are regarded as demanding of attention[22].

In the following sections the main trends regarding favoured theories of attention will be pointed out briefly. Also, important issues on interference with the stages of information-processing and execution of motor responses following processing will be argued.

2.4.2 Theories of attention

In order to be able to form a proper understanding of the various theories of attention, it is necessary to distinguish between the concepts of *serial processing* and *parallel processing*. *Serial processing* is defined by Schmidt (1988b:98) as "[a] style of information processing in which stages of processing are arranged sequentially in time", as opposed to which *parallel processing* can be considered "[a] type of information processing in which at least two processes can occur simultaneously".

The earlier *fixed-capacity* theories held that (Schmidt 1988b:102) "... attention was a *fixed* capacity for processing information and that performance would deteriorate if this capacity was approached or exceeded by the task requirements". Implicit to some of these theories was the assumption of a filter which was located at some stage of the information-processing mechanism; prior to reaching the filter many stimuli could be processed in parallel, thus not requiring attention. The filter then "filtered out" all but one of these stimuli, which was subsequently subjected to attention-demanding "single channel" processing.

Recently, however, the view that attention should be conceived of as "... a *set of pools* of resources" has gained some predominance; such a view makes it possible to explain the fact that it is possible to move for instance the middle finger of both the left and right hand at the same time. Of some importance for piano playing is the notion that it is possible to devote attention to different stages of information-processing at the same point in time; Schmidt (1988b:104) cites complex motor

[22]It is also possible to determine by physiological measurement whether a person "pays attention" - certain changes in skin resistance and pupil diameter, for instance, are usually indications of mental effort, which in turn is associated with "paying attention" (Schmidt 1988b:101).

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tasks such as typing and music sight-reading "... for which attention is thought to be devoted to input (sight reading) and output (finger movement) stages at the same time" as representative examples.

2.4.3 Attention and interference during and after information-processing

2.4.3.1 Interference in the stages of stimulus-identification and response-selection

In the *stimulus-identification stage* of information-processing, processing apparently is accomplished *in parallel* without interference; this is, however, not the case in the *response-selection* stage.

For the purpose of substantiating this statement, Schmidt (1988b:105-106) directs attention to the so-called Stroop phenomenon, named after its Dutch investigator. In an experiment concerned with this phenomenon conducted by Keele (1972), subjects were asked to respond to four different colours by pressing appropriate buttons. These colours were presented either by using irrelevant symbols such as $\pm$, or by printing a specific colour in letters spelling the name of a different colour, for example printing the word *RED* in blue ink. The interesting outcome was that RT for the latter condition was slower than in the first case, even though only the *colour* of the symbol was the relevant stimulus. This phenomenon can probably be accounted for as follows: because the subject has to choose between pressing the "red" button due to the verbal cue implied and the "blue" button because of the colour cue, interference occurs in the response-selection stage of processing. Regarding the stimulus-identification stage, Schmidt (1988b:106) observes the following:

> ... the fact that both stimuli (the color and the word) achieved *memory contact* approximately together implies that the processing of the two patterns in stages prior to response selection must have been simultaneous ... [suggesting] that the processing in stimulus identification occurs in parallel and without attention.

Also of interest to attention and the stimulus-identification stage is the so-called *cocktail party problem*, which is concerned with a person's ability to concentrate on one stimulus within an environment packed with various other stimuli. The nomenclature of this problem is derived from the ability of a person attending a party to engage in conversation with one other person amidst many other conversing people and the general tumult of the party. Furthermore, in spite of the fact that a conscious effort is made to ignore all other stimuli, certain messages always seem to get through, for example hearing one's name spoken. According to Schmidt (1988b:106), the idea of *selective attention* provides a possible explanation for this phenomenon:

> [i]t is as if stimuli from the environment had entered the system simultaneously and had been

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> processed [in parallel] to some superficial levels of analysis, with only those relevant (or pertinent) to the individual being processed further. ... this further processing will usually require attention ... implying that two such activities cannot be done together without interference.

2.4.3.2 Interference and the response-production stage

It has been pointed out earlier that information-processing in its initial phases is principally a parallel event. Schmidt (1988b:109) states that the response-production stage[23], where movements are organized and initiated, "appears to be distinctly different in character. Research studies from various sources point independently to the view that only one movement can be initiated at a time".

The main supporting experimental evidence accounting for the fact that some sort of "bottleneck", or single channel, exists in the response-programming stage, comes from the so-called *double-stimulation paradigm*, in which the subject must react to two closely spaced signals addressing different modalities (e.g., visual and aural) requiring different responses[24]. Investigations of this paradigm revealed that the second of the two closely-spaced responses usually suffered considerably in processing speed, i.e. taking longer to occur in the presence than in the absence of the first stimulus.

Subsequently, a phenomenon termed *psychological refractoriness* was recognized - "... the delay in responding to the second of two closely spaced stimuli" (Schmidt 1988b:139). The practical consequences of psychological refractoriness for motor behaviour can be argued as follows (Schmidt 1988b:138):

> It requires that movements be produced in *discrete bursts* even though the stimuli calling for them are presented continuously. *Interference among two-handed movements, even if planned in advance, is massive if their underlying temporal structures are not similar, suggesting that only one movement at a time can be controlled by a response-execution stage subsequent to RT.* [Italics added]

Schmidt (1988b:112) does point out, however, that some empirical evidence exists which contradicts the hypothesis of a single-channel to account for psychological refractoriness.

Various factors have been found to diminish the delay in RT for the second of the two closely-spaced stimuli associated with psychological refractoriness. Practice has been found to decrease this delay but not eliminating it; thus

> ... suggesting that refractoriness might have a "real" structural basis in the information processing system. (Schmidt 1988b:113)

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[23]I.e., response-programming stage.

[24]This paradigm is described in greater detail by Schmidt (1988b:109-110).

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Stimulus-response (S-R) compatibility, or the degree to which the stimulus and the required response relate to each other, also plays a role; if the compatibility among the stimuli and responses is very high, delays in reaction times can be reduced.

Some noteworthy practical examples of psychological refractoriness, as viewed from the double-stimulation paradigm context, can be traced to certain ball games; Schmidt (1988b:114) cites the example of a player faking an opponent by moving slightly to the right - thus suggesting a fulfledged movement to the right - but then in fact carrying the "real" movement to the left. If his opponent follows the first movement, "... it will require a full RT ... *plus* the added delay caused by refractoriness to *begin* to respond to the second movement", ensuring that his opponent will be too late to counter the "real" movement to the left.

Finally, some attention should be directed to Schmidt's (1988b:114-115) suggestion, based on findings by *inter alia* Kahneman (1973:162 ff.), that "... no matter how small the interval between stimuli - provided they are not grouped and emitted simultaneously - approximately 200 msec occurs between responses". A question, however, immediately arises on the validity of such a statement for piano playing, where it is not uncommon to find time intervals between notes of far less than one fifth of a second (for example in fast scale playing); Schmidt (1988b:115) clarifies this issue as follows:

> The "response" that is planned by the response-programming stage is still one response, but it has many parts that are not called up separately. This can be thought of as *output chunking*, whereby many subelements are collected into a single unit, called a *motor program*... . Also ... these programmed outputs occur in discrete "bursts" separated by at least 200 msec. These discrete elements are difficult to view directly, however, because the muscles and limbs smooth out the transitions between elements, giving the impression that we respond continuously.

2.4.3.3 Attention and interference during movements following information-processing

According to Schmidt (1988b:116), it is possible to identify a conceptual "stage" of information-processing beyond the three stages of information-processing discussed earlier; this stage is associated with that period in time "... in which the individual carries out the movement and keeps it under control".

Schmidt (1988b:117) points out that care should be taken in identifying the focus of awareness during skilled motor behaviour: is it the movement *per se* that requires awareness, the environment, or the programming and initiation of future movements?

It nevertheless appears rather obvious that, while the bulk of attention is devoted to any particular

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component of the movement process, other components have to be executed more or less "automatically". The usual description of tasks performed "automatically" is that these tasks

> ... can be performed without interference from other mental tasks involving (conscious) information processing activities. This fits in with our subjective experiences about "automatic" movements which are done without consciousness. (Schmidt 1988b:119)

It is worthwhile to clarify at this stage precisely what is meant by the adjective *automatic*; according to Schmidt (1988b:108), "... if a process is to be truly automatic, then *any* other simultaneous task should be possible without interference". However, it can been argued that no information-processing activity seems to occur in an entirely interference free manner; Schmidt (1988b:119) therefore emphasizes that "... it is probably best to think of automaticity *with respect to* some other simultaneous secondary task(s)".

Sometimes the RT for a secondary task which is executed simultaneously with a primary task is not higher than when it would have been executed in isolation, indicating that interference does not occur between the two tasks. This fact, however, cannot be taken *per se* to indicate that the primary task is indeed carried out automatically[25]; it merely shows that "... the particular processes needed in *this* ... [secondary movement] task are not also involved in *that* [primary] movement task" (Schmidt 1988b:119).

Of particular interest for the present study is the interference among hand movements which are planned in advance and have to be executed simultaneously. This particular class of movements is characterized by the absence of any obvious environmental stimulus; thus the subject of interference should rather be approached from the viewpoint of control of the relevant limb itself. Schmidt (1988b:120) cites from the field of piano playing the simultaneous execution of different metres in each hand and the playing of *rubato* proper - "... the gradual speeding or slowing of one hand with respect to the other" - as particularly difficult examples. In experiments from motor behaviour science which involved somewhat easier tasks, in which subjects were only required to tap simultaneously different rhythms with each hand, subjects found the said tasks very difficult. According to Schmidt, the motor systems theory interpretation of these findings is generally in terms of motor programs[26];

> ... it is argued that movements are organized with a powerful underlying temporal structure ... [I]t is assumed that only one such temporal structure can be organized and executed at a time, so two tasks with different temporal structures cannot be performed together without massive interference. As a consequence, the motor system appears to "prefer" a mode in which the hands are strongly coupled in time ...

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[25]The so-called *probe technique* experiments from which this conclusion was obtained is overviewed by Schmidt (1988b:118-119).

[26]It is also possible to explain this problem by considering the response-execution "stage" as a single-channel device, requiring for the performance of dual-tasks the same underlying temporal structure.

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A somewhat more subtle occurrence of a similar problem in piano playing occurs in the dynamic shaping of separate voices of contrapuntal compositions, for instance the Bach *Fugues* from *Das Wohltemperirte Klavier*. While the meter in both hands obviously remains the same, the "meter" on a "macro level", i.e. the phrase structure, in general does not correspond for all the voices, except at cadence points; one voice, for example, might enter while another is already halfway through its current phrase. Thus, in a typical four-voiced fugue, where each hand will usually be required to handle two voices, a considerable challenge is posed to the pianist with respect to the simultaneous control of the unique characteristics of each individual voice.

2.4.3.4 Automatic and controlled processing

The essence of the two types of information-processing referred to as *controlled processing* and *automatic processing*, as advocated by Shiffrin and Schneider (1977) for perceptual learning, is conveniently summed up by Schmidt (1988b:107) as follows: controlled processing is

> ... (a) slow; (b) attention demanding, in that other similar tasks interfere with it; (c) serial in nature; and (d) strongly "volitional," in that it can be easily stopped or avoided altogether

while automatic processing is

> ... (a) fast; (b) not attention demanding, in that other operations do not interfere with it; (c) parallel in nature, with various operations occuring together; and (d) not "volitional," in that processing is often unavoidable.

Adams (1987:65) points out that psychologists have believed since 1890 - "without much evidence", though - in the shifting of attention with practice from controlled processing to automatic processing for motor behaviour. However, in spite of various studies and discussions on the topic, there is as yet "... no evidence of a shift from controlled to automatic processing for motor behavior ..." (Adams 1987:66).

In view of the above, this topic will therefore not be pursued any further here.

2.5 Anticipation

In the discussion of motor control so far, it was implicitly assumed that all stimuli are presented in the context of an experimental reaction time paradigm to an unexpectant subject. Therefore, no anticipation by the subject of the stimuli was provided for; a rather unnatural approach when trying to investigate everyday skilled human behaviour, for which "... suddenly presented and unexpected stimuli are the exception rather than the rule" (Schmidt 1988b:122).

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It is possible to distinguish between three different types of anticipation:

- receptor anticipation
- effector anticipation
- perceptual anticipation

Kerr (1982:312,307,311) defines these types as follows: *Receptor anticipation* is anticipation "... in which the performer must also assess the duration of certain external events". *Effector anticipation* is anticipation "... in which the performer must predict the time it will take to perform a movement", while *perceptual anticipation* involves "... the performer ... [identifying] some regularity in the approaching event based only on past experience".

In subsequent sections the consequences of a performer's capability to anticipate in a spatial - or event - sense, and a temporal sense will be investigated.

2.5.1 Spatial, or event, anticipation

Schmidt (1988b:139) describes *spatial, or event, anticipation* as "[t]he anticipation of which stimulus (or the response to it) will occur". When a subject receives information about the nature of a movement in advance, some of the information-processing that is usually confined to reaction time can be done in advance, effecting a decrease in RT when the actual stimulus arrives. When enough information is supplied beforehand, it is even possible to circumvent the entire response-selection stage, especially because one response can be selected and planned while another is being executed (Schmidt 1988b:123-124).

2.5.2 Temporal anticipation and the preparation phase in voluntary motor control

While only a "rather modest" shortening of RT can be obtained through spatial anticipation (Schmidt 1988b:124), experimental investigation into *temporal anticipation* has suggested that "... if the person can anticipate *when* the stimulus is going to arrive, rather large reductions in RT can be made. Under the proper circumstances, the performer can eliminate RT altogether".

The *foreperiod*, in a simple RT test, is the period in time from a warning signal up to the actual onset of the stimulus. For the sake of completeness, some of the effects of varying foreperiod (Schmidt 1988b:124-126) are briefly noted here. For foreperiods of less than a few seconds which occur regularly, with all aspects of the required response being known beforehand, the subject can, after some practice, respond essentially simultaneously with the stimulus. This is however not the

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case when the foreperiod is long, "... because the subject cannot anticipate the *exact* arrival time when it is so far in the future".

Essentially equivalent to the foreperiod in an RT test is Kerr's (1982:255) notion of the *preparation phase* in the voluntary execution of a motor task. A simple example from athletics of the events bordering a preparation phase, can be found in the case of a runner preparing to take off; the "set" instruction given by the starter represents the warning signal, while the pistol shot is the actual stimulus for the start-off. Two subsidiary factors of interest for the preparation phase are termed the sensory set and motor set respectively.

Kerr (1982:217) defines the *sensory set* as

> ... a change in the level of alertness such that the subject increases the rate at which target signals can be processed. This change occurs within the central processing mechanism and not peripherally at the level of the receptor.

Of particular interest is the fact that this increased alertness is not modality-specific; being alert in the expectation of a visual stimulus will also produce a fast RT for an unexpected auditory signal. Also, signals do not have to be as strong as anticipated to trigger the required response: "[n]ot all signals or cues are as obvious as a starting gun. Conceivably, as a spectator in the crowd one could cause a false start by snapping one's fingers before the gun goes off" (Kerr 1982:217).

According to Kerr (1982:310), the term *motor set* in the preparation phase is associated with the selection of the most probable movement under the particular circumstances from the host of movements that is likely to occur.

At the present stage it is not clear how knowledge of the sensory set and motor set can benefit the learner of piano playing.

2.5.3 Benefits and costs of anticipation

Succinctly stated, the benefits of correctly anticipating a movement lies in the short RT for accomplishing the response. On the other hand, if a response is incorrectly anticipated, the "cost" of this error is the time lost in inhibiting the incorrect movement and starting anew with the right motor response. In some competitive ball games, the latter factor could be crucial in determining the outcome of the match; the example of time lost due to incorrect anticipation in a game of football has already been referred to in Section 2.4.3.2. An example of detrimental anticipation in piano playing can be found in the performer who, in anticipating, for example, a difficult octave passage a few

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measures away, prematurely fixes his hand into "octave position"[27], rendering it unfit for the task immediately at hand, namely rapid arpeggio playing (for example), which requires a rather supple hand and fingers.

2.6 The influence of stress and arousal on attention

The subject of performance anxiety under musicians in general - and pianists in particular - has been the subject of considerable interest for quite some time, as attested by the writings of for example Reubart (1985), Lehrer (1987), and Louw (1988). In a great many of the books on piano technique written by musicians, a chapter or two is usually devoted to the problem of "nerves" when performing in public, for example Harrison (1953), Merrick (1958), and Sandor (1981)[28]. According to Neuhaus (1973:88), confidence forms the basis for all freedom in piano technique, and as such should be the foremost goal to strive for. Many problems that seem to relate to the physical apparatus involved in piano playing, such as superfluous movement and stiffness, can in fact be seen as "signs of insecurity with its unpleasant consequences".

While the present study is by no means intended to attempt a treatment of performance anxiety, it is nevertheless worthwhile to investigate - from a motor behavioural point of view - the question as phrased by Schmidt (1988b:130) of "[w]hat effect ... stress and panic have on information processing in these situations that causes people to abandon highly practiced techniques and resort to the skill level of an inexperienced beginner ...".

The terms *arousal* and *activation* can be thought of as representative of the amount of effort exerted by an individual to whatever task he is assigned; these similar states can respectively be defined (Schmidt 1988b:139) as "[a]n internal state of alertness or excitement ..." (arousal), and "[a]n internal state characterized by potential action ..." (activation). Unlike arousal and activation, the concepts of *stress* and *motivation* can not be thought of as "neutral" terms; *stress* is defined by Schmidt (1988b:139) as "[a] *negative* emotional state that tends to direct the individual away from some particular situation [italics added]", while *motivation* can be described as "[a]n internal state that tends to direct the system toward a goal".

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[27]Described in Section 4.2.6.

[28]Already as early as the 1940's more than a superficial interest was maintained in this topic, as can be deduced from the relevant chapter in Ching (1946), which is entitled "Freudian psychology and the pianistic art".

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The relationship between the amount of arousal and motivation has been shown not to be a simple one; instead, the quality of performance varies like an inverted U with arousal as independent variable, which implies that an optimal level of arousal exists, contrary to

> [t]he common belief ... that the more "up" we are, the better we perform. (Schmidt 1988b:132)

As a representative example of the influence of arousal and stress on information-processing, the idea of *perceptual narrowing* is treated here. Increased arousal brings about the narrowing of the attentional focus, resulting in the exclusion of input of stimuli which are relatively improbable. There is also an increase in the "... number of shifts in attention to different input sources" (Schmidt 1988b:133), a phenomenon referred to as *distractibility* -

> ... high levels of arousal are likely to cause the individual to direct attention to many different sources from moment to moment, with some of these sources providing irrelevant information and causing the relevant signals to be missed.

Perceptual narrowing therefore implies that the individual's ability to discriminate between relevant and irrelevant stimuli deteriorates. In extreme cases of increased distractibility, hypervigilance (panic) could result; this term refers to situations in which completely inappropriate actions are taken, due to the fact that not one of the many alternatives that are considered, are considered long enough for the selection of a proper action.

According to Schmidt (1988b:135), tasks that may benefit most from high levels of arousal are "... very simple ... with but a single or a few signal sources and relatively stereotyped responses"; these types of tasks obviously do not include most instances of piano playing, indicating that, for the latter,

> ... telling people to "try harder" does not necessarily lead to gains in skill, and may actually do the reverse. (Schmidt 1988b:136)

2.7 Cybernetics

The theory of cybernetics, which was introduced by Wiener in the post-World War II years, employs the analogy of man as a complex machine; while a computer has systems for input, output, storage and control, a person receives and responds to stimuli, with control and storage provided by the brain. Kerr (1982:37) describes cybernetics in more specific terms as "... a type of closed-loop system in which, characteristically, there is a direct link between output and input based on continual feedback ...".

Of prime importance for the field of cybernetics are the control engineering concepts of the *closed-loop system*, *open-loop system*, *feedback*, and *feedforward control*. The highly complex human

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motor system should be considered as some sort of "hybrid" of closed-loop and open-loop systems (Schmidt 1988b:183).

In order to obtain some insight into the workings of these systems, the closed-loop system, open-loop system and feedback will as a first step be briefly explained in terms of examples from everyday life. Formal descriptions will then be given of the closed-loop system, the open-loop system and feedforward control, with applications to piano playing in the case of the closed-loop system and feedforward control. The subject of feedback will be given a detailed treatment in Section 3.2.

2.7.1 Some concepts from control system theory explained

A closed-loop system can be distinguished from an open-loop system in that the former has feedback from the system response. Thus error detection and error correction are possible for the closed-loop system, while this is not the case for the open-loop system. Examples of an open-loop system and a closed-loop system from everyday life are, respectively, a woodburning stove and an automatic heater (Adams 1987:58). For the wood-burning stove, the heat output simply depends on the amount of wood that is supplied to keep the fire burning - there is no sensing by the stove itself of the degree of heat output or any subsequent adjustment of the fire to compensate for too much or too little heat. The automatic heater, on the other hand, uses the thermostat setting as a reference for comparison with the actual heat output. If there is a difference between the two quantities under comparison, which can be considered the error, the heater will turn on and off until the discrepancy is eliminated.

2.7.2 Closed-loop system

Schmidt (1988b:184) defines a closed-loop system - which can also be referred to as a servomechanism or servo - as "[a] control system employing feedback, a reference of correctness, a computation of error, and subsequent correction in order to maintain a desired state ...".

In Figure 2.2 the basic elements of the closed-loop system of control is displayed diagrammatically. A closed-loop system typically consists of three parts. Input about the goal to be achieved by the system is supplied to a *reference mechanism*. Next, the reference mechanism "... samples the environment that it is attempting to control" (Schmidt 1988b:142) to determine what the current state is with respect to the goal that was set; this information is called feedback. The reference mechanism proceeds to compare "... the value of the goal to the value from the environment"; this difference between the desired and actual states is termed the *error*. The *executive level* uses this error information to decide how it can be reduced to its smallest possible value; if the

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error is not at that value yet, the *effector level* is activated, which causes some mechanism to adjust the environment. The new environmental information is fed back again to the reference mechanism, where a new error is determined, and so forth. The process continues until the error is sufficiently small, whereupon the executive level terminates the activities of the system.

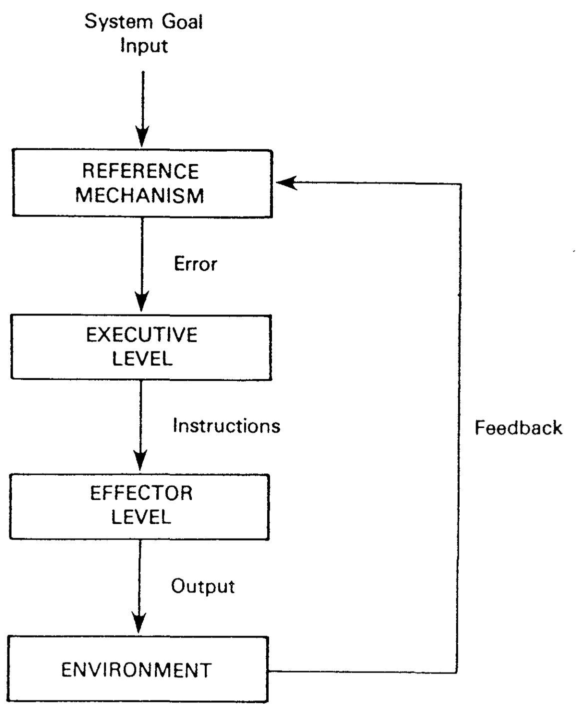

Figure 2.2 Flow diagram showing the basic elements of a closed-loop system of control (from Schmidt 1988b:142).

In the context of the human motor system, the reference of correctness and the executive level of the closed-loop system could be seen as contained in the stages of information-processing, so that feedback would be picked up through the short-term sensory store (STSS) and the stimulus-identification stage (Schmidt 1988b:143). Feedback is received in the form of information from the various muscle, joint and tendon receptors as well as from the visual and aural facilities. The executive level would be considered as part of the response-selection and response-programming stages, while the effector level would actually be the muscles used to effect changes in the environment decided on by the executive level.

At this stage it is appropriate to introduce here a possible representation of piano playing by a closed-loop control system. Although Bridges (1985:9-10) only by implication indicates the presence of a mechanism of reference (which is of critical importance for any closed-loop system), it is nevertheless worthwhile to reproduce here as Figure 2.3 his closed-loop representation of

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unmemorized piano playing, from which one presumably "... can see at a glance all the facets of piano performance that need to be addressed to have a complete understanding of the pianist's skill"[29].

Apparently, Bridges's perceptual mechanism relates to the stimulus-identification stage of information-processing, and his decision mechanism to the response-selection stage. The response-programming stage also seems to be incorporated into his decision mechanism. The effector level identified in Schmidt's representation of the closed-loop system, is accounted for by Bridges' executive mechanism, while proprioceptive information and external results perceived by the other sense organs are fed back "... into the sensory part of the perceptual mechanism"[30] (Bridges 1985:9) in order to evaluate or modify the ongoing motor response.

According to Bridges, the three main components of the control system are constantly exchanging information with memory. Although Bridges does seem to make an implicit distinction between visual memory and motor memory, his depiction of the nature of the latter appears to be rather vague, i.e. it is not clear whether he means, for example, short-term memory, long-term memory, or short-term sensory store[31].

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[29]Unfortunately, it is not clear from which sources in the field of psychology Bridges derived this representation.

[30]Due to the lack of formal definition of concepts which persists throughout Bridges' (1985) thesis, it is not clear what - if any - other parts the perceptual system might have, and how the "sensory" part fits into the whole.

[31]These concepts were treated in Section 2.3.2.

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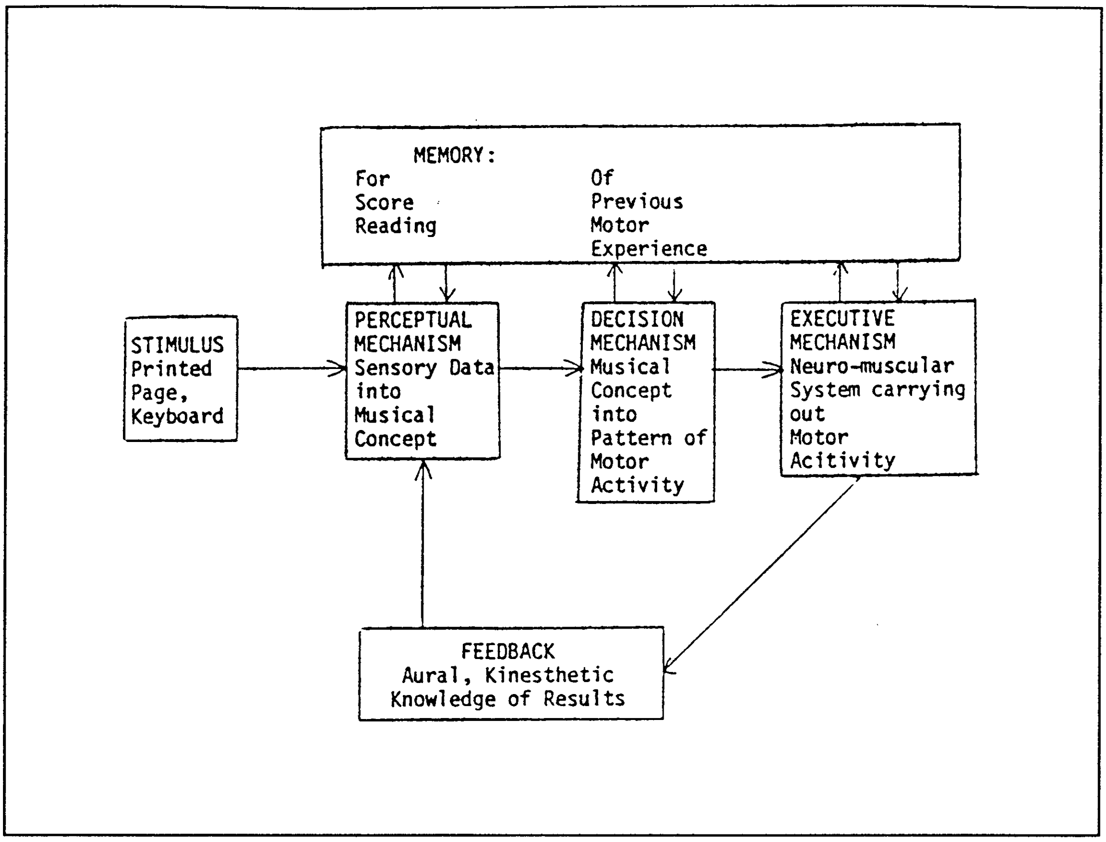

Figure 2.3 A flow chart representation of the facets of piano performance from a score as they function in a closed-loop model (Bridges (1985:10).

Finally, some mention should be made of the concept of *reflexive closed-loop control.* Schmidt (1988b:183) emphasizes that the greatest strength of closed-loop theories lies in their explanation of slow movements, or movements that have high accuracy requirements; closed-loop theories in fact have difficulty in explaining the nature of error corrections as they occur in fast movements. Evidence has however been found for the existence of reflexive closed-loop control, which is based on the premise that the central nervous system contains closed-loop mechanisms that do not require any attention. Reflexive closed-loop control thus differs radically from the conscious information-processing models for control that were discussed earlier. Schmidt (1988b:165) cites an experiment performed by Dewhurst as representative of the manifestation of reflexive control in quite a number of studies: a subject was required to hold a weight in one hand with the elbow kept at a certain angle. Unexpectedly for the subject, the mass of this weight was suddenly increased, and the hand began to move downward, this movement representing an "error" in performance. The brevity of the time period that the hand took to move back to its original position, i.e. correcting the error, suggested that this movement could not have been initiated by an attentionally-based control system of the type discussed earlier; it is rather believed now that control is effected by reflexes in the lower levels of the central nervous system.

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Due to the fact that reflexive closed-loop control is an area of study entailing investigation at mainly the neurophysiological level of analysis, more extensive discussion of the subject falls beyond the scope of the present thesis.

2.7.3 Open-loop system

According to Schmidt (1988b:184), an open-loop system can be defined as "[a] control system with preprogrammed instructions to an effector that does not use feedback information and error-detection processes". The concept of an open-loop system is closely related to that of the motor program, which will be discussed in Section 2.8.

2.7.4 Feedforward control

Feedforward control is described by Schmidt (1988b:184) as "[t]he sending of information ahead in time to ready a part of the system for incoming sensory feedback or for a future motor command". Feedforward control is closely related to the subject of anticipation; it therefore can either ready the muscles of the effector level for forthcoming instructions for movement, or, according to Schmidt (1988b:146)

> ... ready ... reference systems to "expect" a certain signal.

Schnabel (Wolff 1972:20) in his teachings suggested a type of control during piano playing which apparently integrated feedforward with feedback control: "... the performer's inner ear hears everything twice: each little bit is mentally anticipated as well as checked out by later control. If all goes well, these two mental perceptions are blended into one ...". Another pedagogue who apparently advocated the use of feedforward control is Bardas, who used the term *innervation* "... to refer to the imagining at the appropriate fraction of a second before, the exact, most comfortable muscular movement needed to effect the sound that is sought" (Songayllo 1987:62).

Schmidt (1988b:147) notes that feedforward control is especially important for the control of movement in the central nervous system. As investigations of a neurophysiological nature fall beyond the scope of the present study, this theme will not be subjected to closer scrutiny here.

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2.8 Motor programs

2.8.1 Definition and functions

Adams (1987:60), in correspondence with Shaffer (1980:443), defines a motor program as "... an abstract structure in memory that is prepared in advance of the movement ... [containing] the patterns of muscle contractions and relaxations that define movement". The implication of the motor programming concept is that movements are driven centrally; substantial parts of movement sequences can thus be executed without requiring the assistance of response-produced feedback.

Of particular importance for piano playing as a skill consisting of sophisticated, fluent movements, is the contention by Shaffer (1980:443) that three basic functions can be attributed to a motor program, namely

> [f]irst, that it can confer fluency on a movement sequence so that the sequence unfolds at a fast rate, achieving its goals accurately and with an economy of movement. Second, it can confer expressiveness, so that the sequence acquires definite rhythms of timing and intensity, and in dancing or gymnastics it may take on a quality of gracefulness. Third, it has a generative flexibility and so can produce a performance appropriate to its context for an indefinitely large variety of contexts.

The properties associated with these functions will be manifest only in highly skilled performance, whereas unskilled performance may only hint at some of these properties -

> [t]hus, if our aim is to understand the mechanisms of motor programming this is best served by studying skilled performance, observing and interpreting unskilled performance as approximations to, or simpler forms of, this. (Shaffer 1980:444)

2.8.2 Evidence for the existence of motor programs

According to Schmidt (1988b:227), essentially three lines of evidence exist that support the notion of motor programs.

The *first* is the fact that feedback is inherently a slow process, so that movements which are rapid enough will be executed before information can be fed back to the stage of information-processing concerned with detection and correction of errors.

The *second* line of evidence holds that some movements appear to be planned in advance; this is rather clearly suggested by the fact that reaction time increases as the complexity of the movement pattern increases, which in turn indicates an increase in the time required for the response-programming stage. Elaborate and sophisticated movement sequences have to be preprogrammed for

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these increased reaction times not to disrupt the continuity of action.

Thirdly, the idea of motor programming has almost all its roots in experimentation on deafferented lower animals. Deafferentation involves procedures to "... to surgically deny afferent input from a movement by sectioning the dorsal roots of the spinal nerves"[32] (Adams 1987:60). The chief argument then - forming the basis for a generalization from animal to human motor behaviour - is that "[d]eafferented animals typically show some competence ... [thus] the agents of movement do not always need peripheral information and so must be central".

The first line of evidence warrants some further arguing here. Lashley, the originator of the motor programming idea, according to Sidnell (1986:9) held as basic evidence for the existence of motor programs the high trilling speed of concert pianists[33], which supposedly does not leave enough time for proprioceptive feedback. Sidnell, however, is of the opinion that "... most musicians would not agree and could show that feedback is a part of this high-speed rhythmic motor behavior". Of interest here is aural feedback in particular; Wolff (1972:177) in fact describes how Schnabel *listened* to the rapid repeats of the lower note of his trills (rather than to both trill notes equally). Supporting Sidnell's notion, MacKenzie (1986:26) cites results from the field of motor behaviour research in speech, which are sufficiently strong to challenge Lashley's belief that sixteen movements per second are too fast for the incorporation of feedback. This research pertains to auditory feedback in particular, which seems promising, as more findings exist with respect to extremely fast feedback involving other than the auditory facilities.

2.8.3 Motor programs and feedback

While Kerr's (1982:37) definition of the motor program (which corresponds with the earlier definition supported by motor theorists) as "... a sequence of movements, which are performed automatically without any apparent thought ... characterized by its lack of ongoing feedback control" apparently excludes the possibility of feedback, the role of feedback - which does in fact take place - in the motor programming context warrants some further discussion. The main idea here is that, while the motor program does not need feedback from the response to successfully execute the movement, error correction can however be applied, if the movement is somehow perturbed from its course by means of feedback transmitted centrally. This notion was apparently supported by Matthay; in this regard, Bridges (1985:34) points out that Matthay

> ... did not believe in a totally automatic technique. At all times there must be feedback in the

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[32]Afferent input can be described as sensory information supplied from the peripheral organs to the brain (Kerr 1982:189).

[33]In the order of sixteen notes per second.

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form of semi-conscious attention to the kinesthetic sensations of piano playing in order to adapt to any exigencies in the music concept.

According to Schmidt (1988b:228), the functions of sensory information with regard to motor programs can be organized with respect to the time periods

- prior to the movement
- during the movement
- following the movement

Prior to the movement, feedback information is used mainly as information about the initial position from which the movement is launched, or "... perhaps to tune the spinal apparatus" (Schmidt 1988b:265). Evidence has however been found to suggest that

> ... the system can program a joint position without any information about where the joint was before the movement began. ... But various [other] lines of evidence ... indicate that it does not always work in this way ... (Schmidt 1988b:228)

Information about the initial position of the movement is of particular importance for open skills, where the environment is unpredictable, and thus appears not to be of critical importance for piano playing.

During the movement, feedback seems to have a monitoring function in the sense that feedback from the movement is picked up and subjected to processing, but not used to control the movement unless something goes wrong. Schmidt (1988b:232) cites here one of his rare practical examples of immediate relevance for piano playing:

> It is probable that a long string of actions dealing with finger movements in piano playing are programmed and carried out open-loop. Feedback from the fingers is returned to the central nervous system for analysis, as if the central nervous system were "looking for" errors. If no errors appear, then the feedback is ignored. But if the feedback indicates that an error has occurred, then attention can be directed to that feedback source, and an appropriate correction may be initiated.

Feedback *following the movement* is used mainly to determine how successful the outcome of the movement was. Motor learning is benefited in that the movement can be adjusted on a subsequent trial to attempt elimination of errors made in previous trials.

2.8.4 The generalized motor program

To compensate for the fact that, according to Adams (1987:60), "[n]ot every movement segment is assumed to have its own motor program, because it is believed that memory could not store them all", Schmidt in 1976 proposed the concept of what can be termed the generalized *motor program*, or "[a]

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motor program whose expression can be varied depending on the choice of certain parameters" (Schmidt 1988b:265). Succinctly stated, the program is considered to be generalized in the sense that it contains "... an abstract code about the *order* of events, the *phasing* (or temporal structure) of events, and the *relative force* with which the events are to be produced". Movements with specific characteristics can be accommodated by a generalized program through the selection of movement parameters "like force, duration and movement amplitude" (Adams 1987:61). Simply by varying the parameters, the performer should be able to account for a large number of movements with a single program.

It is necessary for a proper understanding of the model to differentiate more closely among the invariant aspects, and variable parameters, of the generalized motor program.

Invariant features that are structurally built into the generalized motor program include (Schmidt 1988b:265)

- the order of events
- the temporal structure, or phasing, of events
- the relative force with which events are to be produced

The phasing of events is concerned with the durations relative to each other - which is extremely important for piano playing for reasons that are rather obvious. When the overall durations of two movement sequences are different, but the ratios of durations of underlying activity of muscles in each case are the same, it can be said that these sequences probably share the same generalized motor program. A similar argument can be conducted for the way in which programs are structured, with respect to the forces that are applied.

According to Schmidt (1988b:255,265), the *variable* parameters of the generalized motor program for which the strongest evidence exists are

- the overall-duration parameter
- the overall-force parameter
- the muscle-selection parameter

The *overall-duration parameter* "... defines the overall duration of the program's action" (Schmidt 1988b:266). While the invariant components of the generalized program include basic sequencing and phasing, only the rate of execution of the *complete* pattern can be sped up or slowed down through assigning a different overall duration parameter. The compression of time intervals within these sequences may however not always be uniform, indicating that changing the overall duration parameter has effects "... more complex than had been originally thought, perhaps because of

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complexities in the muscle properties in fast movements" (Schmidt 1988b:252). A good example of a generalized program which is often required to employ a different overall duration parameter, would be the program functioning to control gait, i.e. the carriage of the human body in moving between destinations (Schmidt 1988b:251): "... the walking pattern (or program) appears to be generalized across different walking speeds, so that we can walk faster or slower by applying an overall speed parameter, keeping the phasing constant". Some reservations do however exist; Handel's (1986) findings, questioning the validity of Schmidt's concept of the generalized motor program, will be discussed in Section 5.3.7.

The function of the *overall-force parameter* in the generalized motor program, according to Schmidt (1988b:266) is to "... [scale] the forces with which the participating muscles will contract in the action". An example from piano playing would be that of a pianist having to proportionally scale up all forces applied to the keys in order to compensate for a piano with a heavier action than one which he is used to. Whether, however, dealing with "difficult" pianos is that simple, is debatable, such a matter being dependent on *inter alia* the sophistication level of the technique of the particular pianist.

Schmidt (1988b:266) describes the *muscle-selection parameter* as "[a] parameter of the generalized motor program related to the selection of the muscles or limbs that will be used in the response". A possible application of the muscle-selection parameter with respect to piano playing, will be pointed out in Section 2.8.5.2.

2.8.5 A motor programming approach to aspects of co-ordination in piano playing

2.8.5.1 The concept of coordination

Perhaps the most often - and most indiscriminately - used term in discussions on piano technique in the literature on piano methodology, is that of *coordination*, which can be defined as the "[b]ehavior of two or more joints in relation to each other to produce skilled activity" (Schmidt 1988b:265). Ortmann (1981:99) describes from a physiological perspective the difference between coordinated and uncoordinated movements as follows:

> A coördinated [sic] movement is a movement which fulfills the requirements of arm-weight, space, and time with a minimum waste of physiological energy. An incoördinated movement is a movement in which this minimum is not reached.

The excessive "waste of physiological energy" associated with an uncoordinated movement may be due to "incorrect weight, distance, or time, as a result of which the aim of the movement is either

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not fulfilled, or is fulfilled by an expenditure of energy greater than is necessary for particular movement". Fielden (1961:66) emphasizes the importance of correct timing of contraction and relaxation of muscles for coordination:

> Stiffness in playing arises from too much contraction beforehand - nervous tension and fear of weakness at the critical moment: too much relaxation before this movement, on the other hand, leads either to flabbiness or to hard, thumping tone. True suppleness lies in securing the full contraction at the right moment, neither before or after: this constitutes *perfect timing*.

Taylor (1979) uses the term coordination in a broader sense than it is used in the definitions above, by essentially regarding the possession of coordination as synonymous to the possession of good technique; in fact, Taylor (1979:18) regards a person's inherent capabilities with respect to coordination and talent for piano playing as inseparable:

> Talent may ... be expressed as *capacity for co-ordination*. It is this that the prodigy instinctively relies upon to provide his means of performance without training and guides him to success as a mature virtuoso.[34]

The fine coordination found in piano playing is described by him (Taylor 1979:18) as "... a particular interaction of brain, body and keyboard which intrinsically precludes any misdirected effort". Taylor (1979:24) emphasizes that (affective) mind[35] and body can not be separated in the matter of coordination. He supports his position by noting that "[p]sychic tensions can create neck tensions which in their turn have a deleterious influence on the general posture", thus affecting coordination adversely. On the other hand, those *improvements* of a sudden nature that occur from time to time in the motor aspects of a student's performance, can also be explained from this point of view:

> ... [a] release of psychic tension would have expressed itself as a release of physical tensions which would have reacted on the total posture sufficiently to ensure that the student made a better use of himself when he came to play the piano.

Any deficiencies in technique can be attributed to a lack of coordination: "... clumsiness in general, and technical failures in particular, have no other origins than in the making of simultaneous contradictory gestures" (Taylor 1979:39). Therefore, when a person's capabilities for coordination increase, the usual technical problems, for example the playing of scales, arpeggios, double thirds, *et cetera*, "... tend to whither away" (Taylor 1979:40).

[34]In view of the above it is rather interesting to note that even concert pianists from the foremost rank have technical problems - or problems with coordination in the sense used by Taylor - in some areas; according to John Browning (Noyle 1987:28), Vladimir Horowitz had trouble with unison scales, while Browning himself is " ... not comfortable with fast double thirds".

[35]A detailed examination of the possible effects of affective factors on motor performance, falls outside the scope of the present study.

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It is of some interest to note that Taylor (1979:39) regards coordinated movements as being of an essentially simple nature. In support of this viewpoint, Thiberge, as quoted by Taylor, states that "[t]he superiority of the virtuosi stems less from their exceptional facilities than from the extremely simple and natural means which they have discovered of using them".

Inextricably interwoven with Taylor's concept of coordination, is his notion of the use of postural control to increase the capacity for coordination; this matter will be examined in detail in Section 4.2.2.3.

2.8.5.2 Coordination between the hands in piano playing

In the field of piano playing, the term coordination often refers to the way the hands combine in the act of piano playing. In Section 2.4.3.3, which deals with interference among movements following the stages of information-processing, the difficulties of performing simultaneously, i.e. hands together, tasks with different temporal structures, have been pointed out. This phenomenon has been explained in terms of the limitations of the ability of humans to construct and execute motor programs; only one temporal structure can be organized and executed at a time. Therefore it is preferable that the individual parts, corresponding to each of the two hands, should have the same underlying temporal structure.

The present section deals especially with conditions that would probably *enhance* the coordination between limbs, in particular the two hands in piano playing. The question of whether one should practise hands together vs. hands apart is also addressed. Once again, motor programming theory, in particular the concept of the generalized motor program, offers explanations for the various phenomena discussed here.

An important, but relatively rare, condition in piano playing, where interference between the hands is restricted to a minimum, as pointed out by *inter alia* Kochevitsky (1967:12), is when one hand executes a mirrored replica of the movement patterns of the other. This is a condition which can perhaps be illustrated most effectively by writing with the non-dominant hand, a mirror image of the words of the dominant hand (e.g. one's name). An analogous example from piano playing is the execution of the diminished seventh arpeggio on B with the one hand, and the diminished seventh arpeggio on F with the other hand in contrary motion. Schmidt (1988b:258) explains why the former procedure is a relatively easy one:

> ... the motor programs for writing - usually directed to the muscles in the dominant hand - were simply coupled to the "same" muscles of the non-dominant hand at the same time. This is consistent with the idea that the selection of the muscles is a parameter that can be applied to a more fundamental and abstract motor program for signing your name.

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Schmidt (1988b:258), however, continues to note that

> [t]his kind of analysis does not ... explain why I cannot simply link the program for writing with the right hand to the muscles with the left hand when it is performed alone. Perhaps, with a great deal of practice, I can ...

Thus, piano-technical tasks, in which the two hands play simultaneously patterns which are mirror images both in the sense of finger movements as well as the topography of the keyboard, should gain from practising hands together rather than hands apart.

Because it possibly could have some relevance to skips at the keyboard with the hands moving in different directions, the conclusions drawn from experiments by Kelso, Southard and Goodman (1979), involving the right hand moving to a large target removed a short distance to the right - with the left hand simultaneously moving to a small target removed a large distance to the left, are also mentioned here briefly. While common sense would predict that the hands should reach their respective targets at markedly different times, it was found that the two hands arrived almost simultaneously -

> ... the two hands appeared to be locked "together" , in that the time of maximum height of the hand, the time for peak acceleration, the shapes of the trajectories, and so forth, were remarkably similar for the two hands. (Schmidt 1988b:259)

As Kelso et al. (1979:1029) phrase it,

> [t]he hand moving to an "easy" [i.e. nearby] target moves more slowly to accommodate its "difficult" [i.e. far off] counterpart, yet both hands reach peak velocity and acceleration synchronously.

According to Schmidt (1988b:260), the explanation for this phenomenon can be interpreted as follows: both hands are controlled by the same general motor program, with phasing characteristics - one of the invariants of the generalized program - being the same in the movements of both hands. But

> [o]ther features ... such as the distance the limbs traveled, appeared to be easily changed between the two hands, and we interpreted this to mean that distance was determined by parameters to the two limbs (an overall force parameter) that were selected differently for the right and left hands.

Along similar lines it is worthwhile to mention here Schmidt's (1988b:416) view on practising hands together vs. hands apart in piano playing[36]: according to him, two-handed piano playing appears to be controlled by a single motor program; therefore

> [p]racticing the movements of one hand in isolation probably results in the development of a different program than practicing that "same" movement in the context of a total two-handed skill ... However, there appear to be contradictions; left-hand piano ... practice seems to transfer to two-hand performances.

These "contradictions" would probably include cases like the Chopin *Etudes*, Op. 10 No. 1 and 2, where the right hand is involved in the execution of highly intricate movement patterns, while the left

[36]Some additional comments in this regard will be made in Section 5.4.2.

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hand is merely playing a simple accompaniment. The coordination between the hands is a rather simple matter in cases like these.

In view of the above, it is rather interesting to note Gieseking and Leimer's (1972:52) viewpoint that it is *not* advisable to allow both hands, in the initial stages at least, to play together when executing scales, but for a different reason, which involves the quality of aural feedback: if the hands do not play separately, "... the left hand is drowned by the right hand, or *vice versa*; for it becomes almost impossible to find out the grade of strength of the different tones with the two hands playing together".

This section is concluded with a statement of Schmidt's (1988b:260) *caveat* that, despite some promising initial investigative attempts, very little remains known about the coordination among limbs that form the basis for complex skilled behaviour:

> [w]hat other patterns of "natural" coordination might exist, as well as which of them are most easily learned, are issues which need considerably more study before we can effectively understand complex skills.

2.8.6 On the extent to which movement is specified by motor programs

Various possibilities exist for the characteristics of the actual instructions comprising motor programs. An older notion that point-to-point computational models, "... in which each point in the trajectory of a movement is represented and achieved by the motor system in the response", is currently regarded as far too complex and improbable to have been achieved by the human control system (Schmidt 1988b:265).

Instead, attention has recently been directed at a dynamical systems approach to motor control, in which the influence on the movement pattern of physical and mechanical properties of muscles and bones are taken into account[37]. Such influences would imply that those aspects of motor control, determined by the mechanical properties of moving masses and the spring-like and oscillatory properties of muscles, do not have to be accounted for centrally by the motor program; thus Schmidt's (1988b:265) observation that

> [c]ertainly, not all of the limb's movement is represented "in" the motor program.

[37]Apparently, this shift in focus is not inherent to the traditional motor systems approach to motor control, as can be deduced from the viewpoint of Bernstein stated in Section 2.9.

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The dynamical systems approach, which is regarded by certain action theorists as an important supporting factor for their viewpoints, will be treated more fully in Section 4.2.7.

2.8.7 A motor programming approach to rhythm and timing

2.8.7.1 Demands posed by rhythmical organization in music on the motor system

The present discussion of the motor programming concept is concluded here with a discussion on how rhythm and timing is maintained in a skilled piano performance. *Rhythm* is defined by Apel (1970:729) as

> [i]n its primary sense, the whole feeling of movement in music, with a strong implication of both regularity and differentiation. Thus, breathing (inhalation vs. exhalation), pulse (systole vs. diastole), and tides (ebb vs. flow) are all examples of rhythm.

Timing in music depends on three different rhythmical entities, namely the *beat*, the *meter*, and *temporal pattern* (Shaffer 1982:109). The term *beat* signifies "[t]he temporal unit of a composition, as indicated by the up-and-down movements, real or imagined, of a conductor's hand (upbeat, downbeat)" (Apel 1970:87). *Meter* is "[t]he pattern of fixed temporal units [i.e., beats] ... by which the timespan of a piece of music or a section thereof is measured" (Apel 1970:523), while *temporal patterns* are constructed through "... joining and subdividing beat intervals to create a series of note and pause durations" (Shaffer 1982:109).

Shaffer (1982) proposed a general theoretical framework to deal with rhythm in its different manifestations associated with skilled activities such as playing music, certain games in sport, and human speech. In each of these types of activities rhythm will differ with respect to stress, periodicity, expression, quality of movement, and temporal pattern.

In order to form a more complete understanding of what would be required of the motor system regarding rhythmical organization in music, it is necessary to consider in particular the rhythmical senses of stress, expressiveness and quality of movement.

In musical performance, rhythmical *stress* has the effect that the listener "... can interpret the meter and clap more vigorously on the strong beats" (Shaffer 1982:110). Stress, however, is not necessarily confined to the meter, and rhythmical variety is typically obtained through redirecting stress from a strong to a weak beat. *Expressiveness* by means of timing is established through judicious tempo variation which involves slight lagging or leading the beat. Rubato, which has been described earlier (see Section 2.4.3.3), falls in this category. The importance of expressive use of

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timing is emphasized by the statement of Shaffer (1982:110) that

> [a] musician who plays squarely on an inflexible beat definitely has not "got rhythm".

Shaffer (1982:110) describes *quality of movement* in an accomplished performance as follows: the performer "... gives the appearance of being unhurried, fluent, and avoiding abrupt accelerations". It follows intuitively that, to achieve fluency, movements have to be prepared in advance of note production, and to achieve a fluent phrase or period, programming has to take place even earlier. It therefore becomes clear that a theory of rhythm should account for, not only the timing of discrete events, but the underlying continuity of motion as well.

2.8.7.2 The concept of an internal timekeeper or clock

For all skills displaying the property of being nearly periodic at some level of the performance, Shaffer (1982:115) proposes that some internal timekeeper, or clock, is present with the ability to construct a required time interval. This assumption appears to be all the more valid for music, which is governed by a beat. The analogy, although rather obvious, should be pointed out here: at the heart of any digital computer system, is an internal clock which provides a regular pulse by which all activity in the system is structured and regulated.

The internal timekeeper of the motor system presumably uses two basic methods (Shaffer 1982:117) for timing a rhythmic group of two beat intervals, from which a variety of more complicated timing structures can be compiled, namely the *concatenational* and *hierarchical* methods. The former simply involves generating the intervals in serial connection, while in the hierarchical method the group interval and the first beat interval are generated; from these the second interval is then determined. In a study involving a statistical analysis of the relationships between time intervals in a Bach *Fugue* from *Das Wohltemperirte Klavier* (Shaffer 1981), Shaffer (1982:118) found that time intervals half a beat in length were apparently generated mostly in concatenation. What made these time intervals of particular importance, was the fact that their length was the same as the note duration found most commonly throughout the piece. On the other hand, the durations associated with shorter notes within half-beat intervals were probably constructed in a hierarchical fashion, "... supporting the idea that the motor system constructed a compound movement trajectory to produce short notes".

On the expressive use of timing, which involved deviations from the beat in both performances in a similar manner, Shaffer (1982:118) notes that

> [h]ere we must suppose that expressive information in a motor program was used to modulate the clock rate. In the nature of our assumption that the motor system uses clock pulses as temporal reference points, it is necessary that both levels of timekeeper, clock and motor system, should receive the expressive information so that they can negotiate chances in tempo

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without becoming radically out of phase.

In Section 2.4.3.3 the difficulty has been pointed out of executing, at the same time, different metric structures with each hand due to a lack of parallel processing capacity in the later stages of information-processing. Shaffer's study (1981:344 ff.) of a pianist performing the first etude from Chopin's *Trois Novelles Etudes*, in which the performer is required to execute polyrhythms of three against four, provides some new insight into this matter. The fact that the pianist was able to manage performing the etude with some expressive timing effects like rubato, and "... one hand moving off and back onto the beat", yet preserving the proper mathematical division corresponding to three and four notes in the beat for the hands respectively, signifies according to Shaffer (1982:118)

> ... the use of a hierarchy of timekeepes: a flexible clock to time the beats and timekeepers in the motor subsystems, one for each hand, to construct the appropriate subdivisions of the beat and allow one hand to move off the beat.

Shaffer (1982:118-119) thus concludes that evidence exists for a clock in piano performance of which the rate can be varied according to the need for expressiveness - "[a] motor system can produce compound movement trajectories that subdivide clock intervals and can undershoot or overshoot clock references in a controlled way".

An interesting side consequence of the work done by Shaffer (1981,1982), is the pointing out of the fact that many research problems concerning skilled motor performance, are not addressed through the traditional methods of introducing subjects to arbitrary laboratory tasks; simply because certain aspects of skilled performance - for instance the expressive use of timing in piano playing - have no counterparts in unskilled activities.

2.9 Limitations of the motor systems approach as seen from the action systems perspective

It can safely be stated that action theorists have at least two major objections against the motor systems approach to motor control.

According to Schmidt (1988a:6), the main point of difference between motor theorists and action theorists has bearing on the concept of the motor program: "[f]or the action proponents ... the notion that some movement programme stored in the CNS is responsible for the controlled actions has been

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particularly distasteful ...".[38] The reason for this "distaste" is the fact that explaining motor behaviour as ruled by the motor program, simply causes other questions of similar magnitude and significance to arise,

> ... resulting in a logically infinite regress. ... if details of ... the timing of an action are controlled by a programme, then how is the programme structured, 'who' structured it, and what are the rules for its formation? (Schmidt 1988a:6-7)

Motor theorists apparently do not have much to offer in response to questions on where motor programs come from; Schmidt (1988b:483), while acknowledging the importance of the problem, simply states that "... the level of knowledge at this time does not allow much to be said about this process [of origination of motor programs]".

Schmidt (1988a:7) singles out as a further argument of particular significance against the motor program, Bernstein's (1984) notion that

> ... it is ... impossible for the CNS to be able to 'compute' the exact commands needed for a particular action ...[39]

This implies that a central motor command cannot determine action unequivocally (Bernstein 1984:82), the reason being that the command can be modified before actual execution due to either sensory information becoming available, or the state of the limb(s) caused by the command just prior to the command being executed:

> ... sensory information from the responding limb (and elsewhere) can exert its influence as the movement is unfolding, thus modifying any central command structure before it is received at the muscle level. ... [Also], various sources of muscle non-linearities make the forces produced by a given central command different depending on various initial conditions in the limb and muscle.

Action theorist's alternative for the motor program, namely accounting for order in movement patterns through the dynamical properties of the moving limbs, will be examined in Section 4.2.7.

A second major objection, in this case aimed against the traditional methods for studying motor behaviour, is stated by Sloboda (1988:vii); it involves the rather easily-observed phenomenon that problems of measurement in motor behaviour science led to the concentration within the psychological community on tasks that are relatively simple -

> [i]t is always easier to collect one's data in the form of responses from a limited and pre-ordained set (for example yes-no decision, same-different decisions) than it is from relatively unconstrained and multi-dimensional behaviour.

In addition, the difficulty exists of devising suitable controls over experiments involving generative behaviour; without such controls it becomes increasingly difficult to extract generalities, which in the

[38]The acronym CNS stands for central nervous system.

[39]This fact has of late been recognized by some motor systems theorists as well, as was indicated in Section 2.8.6.

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end is what a scientific investigation is all about (Sloboda 1988:viii).

A similar position is held by Mulder and Hulstijn (1988:253), who regard as a major deficiency of the motor systems approach, the artificiality of its theories, which are derived from simplistic experiments in an impoverished controlled environment: " [t]oo often movements are unduly trained and studied independent of the actions of which they are elements" (Mulder & Hulstijn 1988:254). In the context of piano playing, similar ideas are voiced by certain pedagogues; Thiberge, as quoted by Taylor (1979:38), held the rather disconcerting view that it is of little use to study in isolation (for instance) the contrary muscular exertions of which the body is capable:

> As all the parts of the body are so intimately bound up with each other, the entire body of the pianist is capable of giving rise to exertions which are destructive to the suppleness of the fingers, and for that matter, the suppleness of the limbs in general.

Even Schmidt (1988a:11), who conceived the generalized motor program, notes that motor processes initially went through an evolution in order to help the animal adapt to his environment; therefore

> ... principles learned from experiments in artificial and constant environments may be at worst fundamentally different from those involved in real animal-environment situations, or, at best, may simply be irrelevant to them.

Finally, Reed's (1988:79) denouncement, in rather harsh terms, of the cybernetics concept and its predecessor trends in psychology deserves some attention:

> This so-called 'science of human movement' *assumed* that all acts could be standardized and timed into 'optimal responses'. ... These scientists emphasized the need to act quickly, on a signal, and to quickly modify responses through sensory correction. ... The human brain began to be treated as a little machine inside the bigger machine of the body, the body being the 'interface' to other machines and the environment for the brain. To put it bluntly, the modern sciences of human movement have tended to treat our actions as though they were the constrained movements of a gunner or a welder on the assembly line.

The different, supposedly "better" approaches to motor control advocated by action system theorists will be treated in Chapter 4[40].

2.10 Summary and conclusions

Piano playing, due to its complex nature, apparently displays the characteristics of both serial and continuous motor tasks. Any piece which in refinement approaches concertizing standards, apparently assumes predominantly continuous characteristics. This is because attempts to create a musical *Gestalt*, would probably de-emphasize any pronounced demarcations into the constituent element

[40]In Section 4.2.3 some additional criticism of the motor approach will be presented on account of its inability to explain postural precedence effects.

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sections of the piece. Whether piano playing is regarded as a closed or semi-closed skill will depend on the nature of the learner's involvement with music. Apparently, the matter of explicitly accounting for piano playing as a semi-closed skill in a strategy for practice, is largely ignored in the piano methodology literature.

Methods have been described for quantifying scientifically both movement characteristics and movement outcome. Methods currently employed in the psychological community for measuring movement characteristics could be difficult and cumbersome to employ in studying motor responses in piano playing, simply because of the large range of small muscles and the great variety of refined movements involved. Describing movement outcome - for instance through using the experimental techniques of Shaffer - appears to be a viable proposition for studying certain aspects of the performance. Also, it should be possible to investigate in a similar manner the presumed variables of the generalized motor program; an increased overall-force parameter, for example, would manifest itself in higher hammer shaft speeds, which can be detected electronically. It is redoubtable whether measuring movement speed in piano playing through reaction time tests would be of much significance, as there are simply too many refined complex movements, most of which are interrelated, which constitute the act of piano playing. The implicit understanding associated with measures of speed, that accuracy is of less importance than rapid actions, does not appear particularly attractive to piano playing either.

It was pointed out that motor system theorists regard man as a so-called "black box", which processes input signals from the environment in order to output appropriate motor responses, and that from overt human behaviour observed inside the laboratory and in everyday life, it can be inferred that information-processing takes place in three stages. The significance of studying these stages in piano playing will essentially depend on the nature of the movement task. In the initial stages of getting acquainted with a passage, it is reasonable to assume that a motor response could be the equivalent of playing a single note. Then, the three stages of processing could, among various possibilities, typically proceed as follows: the aural stimulus is the note played just before, and it is recognized in the context of the passage; a motor response is selected from any number of combinations of finger movements relating to different keys on the keyboard, and finally the muscles of the appropriate finger(s) are readied to strike the right key or combination of keys; in the case of for instance a five-finger run, a short motor program would be prepared. In a polished performance of a piece consisting of many hundreds of notes, the playing of a single note can hardly be conferred the status of a fulfledged motor response; in this case, what comes next is determined mainly by motor programs acquired through extensive practice.

Much uncertainty is prevalent on the subject of motor memory. The conceptual distinction

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between short-term memory and long-term memory is at the present time regarded to be of little significance. It is not clear if and how knowledge of the concept of the short-term sensory store, could aid control and learning of the problems involved in piano playing.

It was found that the lack of continuity in the response-programming stage suggested by the phenomenon of psychological refractoriness - movements can only be produced in discrete bursts spaced at intervals of at least 200 msec. - should not influence the "flow" of action in piano playing, especially in view of the fact that each of the discrete bursts of movement may be controlled by a motor program, and thus movement may be maintained for sufficiently long (i.e. 200 msec. at the least) until the next set of movements arrives, ensuring continuity.

In the execution of motor responses following the stages of information-processing, the question of automaticity comes strongly to the fore. No kind of information-processing seems to be entirely free of interference. It was pointed out that a task should only be thought of as automatic with respect to some other, secondary task. Two tasks carried out without apparent interference, however, does not necessarily imply automaticity, because it is possible that the two tasks simply use different processing facilities. More investigation is needed to determine whether this notion is of particular significance for piano playing. The massive interference that occurs when two tasks with different underlying temporal structures have to be executed, for example the application of rubato, can be explained by using the argument that movements are organized by the motor system under a strong temporal structure. It was furthermore pointed out that no conclusive evidence exists for the progression in motor activities from controlled information-processing to automatic processing via practice, which intuitively seemed a most acceptable proposition.

It appears as if knowledge of spatial and temporal anticipation can serve to clarify aspects of motor control in piano playing, especially if it is assumed that timing is organized by some sort of internal clock in the motor system. Spatial anticipation in (slow) piano playing could occur as follows: the playing of a particular note would serve as a "warning signal" for the next note, so that the performer will be ready when the actual stimulus, for example the next beat or its relevant subdivision as supplied by the "internal clock" of the motor system, arrives. Due to the fact that piano playing is a rhythmical activity, the pianist can easily anticipate in a temporal sense when the next stimulus will arrive, resulting in an essentially simultaneous response with the stimulus. Anticipation can, however, be detrimental in that anticipating the musculature conditions required for a certain response, could inhibit execution of the current movement pattern for which a different configuration of the playing apparatus is needed.

The often-observed fact that too much arousal can be detrimental to piano playing, especially in

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the case of public performance, can apparently be explained from an information-processing viewpoint: because of perceptual narrowing, the performer's ability to distinguish between relevant and irrelevant stimuli is adversely affected, which consequently takes its toll on the performance. As with so many areas in motor control, the question regarding optimum arousal levels is not cleared up yet; it is however worthwhile to note that constant exhortations to "try harder" may produce just the opposite to the intended effect.

Three models from control engineering were proposed to account for human motor control, the closed-loop and open-loop models being the most important. An extremely attractive feature of these models is their underlying simplicity. As most of the motor systems theorizing on motor learning and motor programming are based on these models, the question could be raised of whether these models are perhaps too predictable in their simplicity and regularity to account for the infinitely rich variety of movements humans are capable of, not the least manifestation of which is playing the piano.

Although motor programs are seen as open-loop methods of control, some use is made of feedback to correct errors, if any, during execution of the program. Therefore, the notion that a section involving rapid passage work is controlled "automatically" by a motor program, should not let the performer refrain from monitoring his playing through constant listening, because the concept allows for adjusting the program to compensate for errors in the execution of the program as well as unforseen environmental effects, such as a piano with an uneven action.

The generalized motor program concept was introduced to improve the original motor programming idea; it also raises some questions, however. To illustrate some of these questions, consider a virtuoso Chopin *Etude* as controlled by such a program. Changing the overall-duration parameter would imply speeding up or slowing down the tempo as desired, while changing the overall-force parameter, would suggest that all dynamic levels can be scaled up or down, maintaining their relative proportions. However, it does not take a particularly astute perception of the problems of piano playing to realize that only the most accomplished of pianists would be able to meet these demands. Perhaps this implies that the best pianists are the only persons who know how to properly structure generalized motor programs in piano playing. Further research is necessary to clarify this concept with respect to piano playing; some more findings in this regard will be discussed in Chapter 5.

The term coordination can be shown to incorporate under its banner a fairly wide variety of meanings, which apply to *inter alia* movements *per se*, and talent for piano playing. Apparently however, explanations, based on motor systems premises, of coordination problems in piano playing, pertain mainly to the coordination between limbs, i.e. the hands, in piano playing. In particular, a

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generalized motor programming explanation was offered for the relative ease with which the hands execute parts that are mirror images of each other. Of quite some importance was the pointing out of the notion that practising one hand alone, probably results in a different motor program than practising the movement patterns of the same hand in the context of the two-handed skill. When the other hand merely adds a non-exacting accompaniment, it is probably in order to practice the "difficult" hand alone, as coordination between the hands is relatively easily obtained. Once again, more research is necessary to fully understand the complexities of coordination between limbs, in particular the hands in piano playing.

Not all the intricate - sometimes microscopic - details of movements are identified in and controlled by the motor program; some of these movement characteristics are accounted for by the mechanical properties of the relevant muscles and limbs. According to certain action theorists, *all* movement characteristics can be explained in this way; this matter will be taken up for further discussion in Chapter 4.

Shaffer's notion was discussed that rhythm and timing in piano playing can be accounted for by the digital computer concept of an internal clock. In fact, all nearly-periodic skills can be thought of as structured in this way. For the execution of polyrhythms divided between the hands with expressive timing effects superimposed, two flexible clocks are used, one for each hand. Shaffer's investigations brought another point to the fore, namely that highly-skilled motor tasks, such as piano playing, cannot be addressed by laboratory experiments involving simple motor tasks and unskilled test subjects, because certain aspects of skilled performances have no counterparts in unskilled tasks. Thus, due to the large investment in time required for unskilled subjects to become skilled in some task, many aspects of skilled motor behaviour remain uninvestigated.

Two major objections of action systems theorists against the motor approach were singled out. Firstly, action theorists categorically deny the existence of central control, i.e. motor programs. If this premise should prove to be true, most of the above notions and conclusions would apparently be rendered irrelevant. The second objection involved the irrelevancy for highly-skilled motor tasks (like piano playing) of experiments involving simple, unskilled motor tasks performed in an impoverished controlled environment. This objection is of considerable significance, especially when it is realized that all theories of motor control and learning have in the first instance to be based on some sort of experimental premise.

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CHAPTER 3

THE MOTOR SYSTEMS APPROACH TO MOTOR LEARNING WITH SPECIAL REFERENCE TO PIANO TECHNIQUE

3.1 Introduction

While motor learning research has been in progress for over a century, Schmidt (1988b:15-16) states that the late 1970's and early 1980's are characterized by a decline in interest in the field of motor learning. This decline can be attributed to an increase in interest in motor control and the information-processing approaches associated with motor control; "[t]his is unfortunate because the issues involved in learning have perhaps the most practical applicability to training ... and teaching in general" (Schmidt 1988b:16). Nevertheless, two of the three[1] fundamental theoretical models for learning - which "... may have great relevance to our problems in music education" (Sidnell 1986:8) have gained particular prominence around these dates, namely the closed-loop theory of Adams and schema theory as formulated by Schmidt[2].

At this stage it is appropriate to note that all theories of learning essentially attempt to explain a certain generalizable finding, termed the *law of practice*, which states that "... the log of the performance tends to change linearly with the log of practice" (Schmidt 1988b:491). This logarithmic relationship between practice and performance can be explained as follows (Schmidt 1988b:460):

> ... the rate of improvement at any point in practice tends to be linearly related to the "amount left to improve" in the task. So, early in practice, when there is much learning left to accomplish, the speed of improvement is very rapid as compared to the end of practice when there is not so much "room for improvement" remaining.

In the following sections the fundamental concepts of motor skill, motor learning and transfer of

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[1]Motor programming, which is considered by some, for example Sidnell (1986:8) to be a third theory of learning, has been discussed in Section 2.8.

[2]The notion of motor schema is not new, however.

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learning will be examined more closely.

3.1.1 The concept of motor skill

3.1.1.1 Definition of motor skill

While Kerr (1982:310) describes a motor skill as "any muscular activity that is directed to a specific objective"[3], the definition by Guthrie (1952) can possibly be regarded as the best of its kind (Schmidt 1988b:3): "[s]kill consists in the ability to bring about some end result with maximum certainty and minimum outlay of energy, or of time and energy".

Contrary to what the previous definitions may suggest, the description and identification of skilled motor behaviour is not necessarily a simple or clear-cut matter. This is due to the wide range of behaviours that can be regarded as skilled, the fact that skilled behaviour is evaluated according to its level of competence or proficiency, and the fact that not solely motor processes are involved in the execution of motor skills. These points are illuminated in an extended definition of the more general term *skill* by Adams (1987:42):

> 1. Skill is a wide behavioral domain. From the beginning, skill has meant a wide variety of behaviors to analysts, and the behaviors have almost always been complex.
> 2. Skill is learned. That skills can lack proficiency, and acquire it gradually, with training, conflicts with the dictionary definition of skill, popular usage, and how a number of investigators have used the term. A dictionary and a layman will define skill as the ability to do something well, and psychologists have often said the same thing... No investigator, however, should have more than a passing interest in behavior at its asymptote; a scientific understanding of skill must be concerned with all grades of it.
> 3. Goal attainment is importantly dependent on motor behavior. Any behavior that has been called skilled involves combinations of cognitive, perceptual and motor processes with different weights. Mathematicians have cognition heavily weighted in the description of their behavior, with virtually no weight for perception or the motor response with which they write the answer to a problem. On the other hand, the behavior of tennis players could not be meaningfully described without including the motor responses stemming from their perceptual evaluation of the situation and the cognition in their decision making.

In view of the above, it should be pointed out that the term skill, as used in the present study, implies motor skill; skilled performance therefore is predominantly muscular[4].

In his discussion on motor skills, Kerr (1982:18) notes that when the muscles are tired, the

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[3]All muscular activity not consciously directed toward some objective, such as all reflex activity and muscular twitches, is excluded from the definition of motor skill (Kerr 1982:5).

[4]Thus, as is usually found in motor behaviour science, the cognitive processes involved in skilled motor behaviour are not emphasized *per se* in the present study.

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performance[5] may deteriorate, but the skill is not lost. It is, however, of some significance to note that in the bulk of the literature on piano technique, the view is held that the "building in" of measures to prevent the muscles from getting tired - at least to a degree where the quality of the performance is not influenced - is implicitly part of the process of attaining technical skill. The pianist Alek Peskanov (Elder 1986:12), for instance, recalls his teacher indicating to him that he would never get tired provided he employed the "correct" physical strategy - "... I don't get tired because she showed me so many positions of the hand."

3.1.1.2 Classification of motor skills

In order to organize the field of psychomotor[6] learning, which encompasses an infinity of motor skills of varying degrees of difficulty, the concept of taxonomies were introduced. The term *taxonomy* refers to "... an orderly classification according to presumed natural relationships" (Kerr 1982:9). Several benefits are attached to the concept of taxonomies. By identifying and describing the common elements between motor skills, understanding of these skills is enhanced. Directing research efforts at the common elements between motor skills makes the research findings more generally applicable. Also, the effect of a particular teaching technique on different motor skills belonging to the same category can be studied (Kerr 1982:9-10). It is of some importance to note in the context of the present study, Reed's (1988:46) pointing out of the fact that, up to the present, all taxonomies of human skill adhere to the assumption that all skills are built up out of "... elementary neurobehavioral units".

While it is not of particular interest for the purposes of the present study to discuss the classification *per se* of the vast amount of different types of motor skills, insight can nevertheless be gained into the classification procedures by considering the three main categories of motor skills as proposed by Kerr (1982:6):

1. The *phylogenetic skills*, or the skills common to all humans that are developed in early life and that are dependent on maturation. Examples are walking and talking.
2. The *communication skills,* which are essential for educational development. Examples are writing and reading.
3. The *recreational skills*, or those skills "learned for oneself". Examples are painting and playing a musical instrument.

The last two categories are often referred to as the *ontogenic skills*, i.e., skills learned by and unique to an individual, requiring a conscious effort on his part.

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[5]*Performance*, as opposed to motor *learning*, will be defined in Section 3.1.2.1.

[6]The significance of the prefix *psycho* will be explained in Section 3.1.2.1.

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3.1.2 The concept of motor learning

3.1.2.1 Definition of motor learning

Kerr (1982:6) defines *motor learning*[7] as "... a relatively permanent change in the performance of a motor skill resulting from practice or past experience", where *performance* can be defined as (Kerr 1982:5) "... a temporary occurrence fluctuating from time to time: something which is transitory". For Kerr, experience includes not only actual execution of the motor skill by oneself, but also the observation of others performing, for example watching the teacher perform.

Establishing a shift in emphasis away from outward behaviour of the learner, Schmidt (1988b:346) describes motor learning as a collection of internal processes[8]; the nature of these internal processes is "... what learning theorists try to understand". In particular, motor learning is (Schmidt 1988b:375) "[a] set of internal processes associated with practice or experience leading to relatively permanent changes in the capability for skill".

For purposes of further elucidation, Schmidt's (1988b:345-346) explicit identification of the four distinct characteristics of motor learning implied in the definition above is reproduced here:

> First, learning is a *process* of acquiring the *capability* for producing skilled actions. That is, learning is the set of underlying events, occurrences, or changes that happen when practice enables people to become skilled at some task. Second, learning occurs as a direct result of practice or experience. Third, learning cannot (at our current level of knowledge) be observed directly, as the processes leading to changes in behavior are internal and are usually not available for direct examination ... Fourth, learning is assumed to produce relatively permanent changes in the *capability* for skilled behavior; changes in behavior caused by easily reversible alterations in mood, motivation, or internal states (e.g., thirst) will not be thought of as due to learning.

The internal capability for responding is termed *habit* by Schmidt (1988b:346) following the designation by James of 1890. Defining learning as a capability for skilful action implies that, once the capability for responding is established, the skill may either be executed - when the external conditions are favourable, or refrain from being executed if, for example, fatigue is present or motivation is low. Thus, the definition of Schmidt clearly provides for the important distinction between learning and performance pointed out earlier; "... behavior may vary for a number of reasons, only some of which are a result of a change in the internal capability for responding

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[7]Motor learning can also be considered a field of study; in this case "[a]n area of study focusing on the acquisition of skilled movements as a result of practice" (Schmidt 1988b:17).

[8]A *process* is "... a set of events or occurrences that, taken together, lead to some particular product, state, or change" (Schmidt 1988b:346).

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produced by practice" (Schmidt 1988b:347).

Not classified under the heading of motor learning, are all changes in the capability for responding not acquired through practice; these typically include changes due to maturation and aging and temporary changes in the physiological state of the learner, such as fitness level (Schmidt 1988b:347).

Finally, on consideration of the perspectives from which the present study is conducted, the important distinction between the concepts of *motor learning* and *psychomotor learning* should be pointed out. The prefix *psycho* in the latter signifies, according to Kerr (1982:6), "... a large central control operation that not only supervises the specific muscle commands regarding *how* to move but also supervises the decisions of *why*, *when*, *where*, and *how far* to move". Because action theorists reject the idea of central control, the more general term *motor learning* is therefore used in this thesis.

3.1.2.2 Transfer of motor learning

Schmidt (1988b:371) defines *transfer of learning* as "... the gain (or loss) in the capability for responding in one task as a result of practice or experience on some other task".

To illustrate the transfer concept, the question might be asked if, for instance, practising the harpsichord would produce benefits or losses - or neither - for a task like piano playing. If it appears as if piano performance is more skilful after practising the harpsichord than it would have been under no beforehand experience of the harpsichord, it is likely that *positive* transfer has occurred of the harpsichord skills to playing the piano. If, on the other hand, the learner's performance at the piano is worse after practising the harpsichord than it would have been if the learner did not practice the harpsichord at all, then *negative* transfer of the harpsichord skills to the piano playing skills has occurred.[9]

3.2 Feedback and knowledge of results (KR)

The information that a performer receives about his performance while attempting to learn a skill, is termed feedback. Feedback, which can take many forms in the environment or laboratory, can also be regarded as (Schmidt 1988b:454) "... [s]ensory information that is contingent on having produced a movement". According to Schmidt (1988b:423), feedback information is, next to practice, the most

[9] The reader interested in this interchange involving the piano and harpsichord is referred to Martinez (1990) for more information.

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important variable for motor learning:

> Understanding the principles of how such performance information "works" will provide additional bases for the decisions about the design of teaching or training environments.

It is possible to divide *response-produced feedback*, i.e. information produced during or after the movement, into two broad sub-classes, namely

- intrinsic feedback
- extrinsic feedback

These two classes will now be considered in greater detail below. Of course, the underlying assumption will be that motor learning occurs in a closed-loop situation where the task is repeated until it has been mastered. During and after each trial, feedback information is used to improve the next trial, and so on, until the task is mastered after enough trials have been performed.

3.2.1 Intrinsic feedback

Intrinsic feedback is "[t]hat feedback normally received in the conduct of a particular task" (Schmidt 1988b:454), being a direct consequence of the movement (Kerr 1982:309). Intrinsic feedback is picked up through various sensory channels, for instance the aural, visual and tactile facilities of the pianist. Closely associated with intrinsic feedback is the concept of *subjective reinforcement*[10], "... the subject's self-generated error signal, based on comparing feedback against a reference of correctness" (Schmidt 1988b:455). Not every performer uses intrinsic feedback to the full; it may be necessary for the pianist to be taught how to exploit useful aspects of intrinsic feedback. Thus the student could typically be taught to make sure, through awareness of physical sensations, that the thumb in scale playing remains free of unnecessary tension, for example.

In subsequent sections three types of intrinsic feedback that are relevant to the pianist will be discussed. These types of feedback are *aural feedback*, *kinesthetic feedback* and *visual feedback*, aural and kinesthetic feedback probably being the predominant types of feedback in piano playing.

3.2.1.1 Aural feedback

The use of aural feedback consists thereof that the pianist will constantly be listening to aesthetic aspects of his performance, like tone quality, phrasing and timing, bringing about appropriate changes in motor responses where required.

[10]This topic will be explained more fully in Section 3.4.1.2.

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According to Gieseking (Gieseking & Leimer 1972:5), the critical "self-hearing" associated with aural feedback is "by far the most important factor in all of music study". As Lhevinne (1972:11) notes, "[t]he finest students are those who have learned to listen". Gieseking points out that self-hearing is essential for a good technique, and that it can be developed through training[11]:

> Only trained ears are capable of noticing the fine inexactitudes and unevennesses, the eliminating of which is necessary to a perfect technique. Also, through a continuous self-hearing, the sense for tone beauty and for finest tone shadings can be trained to such a degree that the student will be enabled to play the piano with an irreproachable technique ...

Under Leimer's method, this training effort is focused on the detection of firstly tone quality, and secondly tone duration (Gieseking & Leimer 1972:20).

It is common knowledge that, because of numerous subtleties involved, the use of aural feedback is far from simple or straightforward. According to Gieseking and Leimer (1972:10), most pianists do not hear themselves correctly, in spite of the fact that they are quite proficient at spotting wrong notes: "[f]or the pianist the noticing of the exact tone pitch is ... only secondary when compared with the noticing of the exact tone quality, tone duration and tone strength". This view is endorsed by Reubart (1985:88), who states that many pianists tend not to listen to what they are playing "... not because they do not choose to, but because they do not realize that they are not". Instead, these pianists perceive only what they expect to hear. Prostakoff and Rosoff (Whiteside 1969:22), and Whiteside (1969:28) observe that a musician's ear can be "conditioned" by his practising habits. An example is the predominant involvement of a performer with those parts of his playing apparatus involved in the articulation of individual notes, resulting in an ear that listens "notewise" and neglect of the well-being of larger units, like phrases.

3.2.1.2 Kinesthetic feedback

Kerr (1982:309) describes *kinesthesis* as "... the awareness of body position and movement based on proprioceptive information"; according to Harrow (1972:58), kinesthesis is manifested by the physical sensation experienced by an actor during the execution of a motor response[12]. For all practical purposes, kinesthesis is the same as *proprioception*, which was defined in Section 1.5.

Exhortations to become acutely aware of physical sensations, which is not necessarily a matter of large, easily detectable differences, are common in the literature on piano playing. Some representative examples will now be examined. Bridges (1985:28) notes that, while the words mostly

[11]An idea which corresponds with Gibson's notion expressed in Section 4.2.8 that the perceptual systems can be trained to function more effectively.

[12]Discussion of the various receptors responsible for kinesthesis falls beyond the scope of the present study; Schmidt (1988b), however, devotes attention to this topic.

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associated with Matthay's concept of technique are "weight" and "relaxation", the term "invisible technique"[13] most aptly sums up its essence:

> To him, technique was not just a matter of getting the visible motions right, but rather of properly coordinating the actions of the limbs by attending to the feelings associated with muscular contraction and relaxation.

According to Whiteside (Prostakoff & Rosoff 1969:22), the nature of the physical nuances involved in piano playing are such that they can only be felt, not seen or even heard. Gieseking and Leimer (1972:110) recommend in an explanation on the achievement of a so-called singing tone, that the fingers should be held straight rather than curved, allowing the keys to be depressed by the "... flat part of the first joint of the finger ... [i]n this manner the delicate sensory nerves of the fingers come into their own, making it possible for the player to bring forth a large scale of rich tone colors". Furthermore, instructions given by Neuhaus (1973:116-117) for practising trills rely heavily on the employment of kinesthetic feedback: the pianist should ensure active participation of the fingers only, practising the whole range of dynamics and speed. Sensory awareness can be enhanced by playing "... without at all raising the fingers over the keys so that not even a ... razor blade could be slipped between the fingertip and the key surface". Merrick (1958:52) describes procedures by which firmness of the hand combined with flexibility at the wrist can be made familiar in sensation. And Hoffman (1920:11) recommends that the division of labour between the limbs involved in the execution of tremolos can not be done consciously, but should rather be determined by the "right" feeling.

Reubart (1985:137-138), on the other hand, warns against a misplaced emphasis on the kinesthetic experience which is manifested in the myth that the player "... must be muscularly *tense* if he is to be musically *intense*". Such an emphasis could give rise to a detrimental kind of closed-loop system, in which both overly tense muscles and performance anxiety are role players: "... signals from the straining muscles form a feedback loop with the central and autonomic nervous systems to create and sustain performance anxiety that is often out of control". Reubart (1985:142) furthermore stresses that this problem is far from uncommon:

> The feedback loop linking high muscular tension/high performance anxiety, musical intensity-muscular tension/high anxiety can be seen almost every day among some of our most talented student performers.[14]

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[13]Compare the title of his monograph *The visible and invisible in pianoforte technique* (1947).

[14]One can only speculate on the extent to which statements like those of Slenczynska (1974:39) on the execution of the left-hand octaves in Chopin's *Polonaise* Op. 53 - "[y]ou will suffer physical pain and learn to endure it" - will cultivate the existence of such feedback loops.

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3.2.1.3 Visual feedback

Visual feedback[15] in piano performance is obtained through observation by the pianist himself of the motion patterns of his fingers, hands, wrists, elbows, arms and other members of the playing apparatus involved at any time; the approach to piano technique of Phelps (1981) for instance, relies heavily on the use of visual feedback. An indication of the nature that visual feedback information can assume in the playing of scales and arpeggios, is found in the relevant guidelines by Sandor (1981:70-71), some of which are reproduced below:

> 2. Each finger is to be helped by the rest of the playing apparatus, which assumes a corresponding position suitable to that particular finger.
> 3. The need for changing positions for each finger results in continuous adjusting movements of the arm.
> 4. In general, the wrist is at its lowest point when the thumb is used and at its highest point when the fifth finger is used.
> 5. Guideline 4 is modified when grouping of notes is involved; in groups the lowest wrist position is assumed at the beginning of the phrase, no matter which finger plays, and the highest position is assumed at the end of the phrase ...
> 6. When we play scales we should avoid placing the thumb under the palm; instead we should place it alongside the hand. A combined finger-wrist-arm motion prevents a cramped and uncomfortable position for the thumb.
> 7. Whenever the hand is in playing position, we should avoid an extreme pronation of the radius and ulna ... by slightly raising the upper arm.
> 8. The technique for scales and arpeggios is fundamentally the same, except that in arpeggios wider intervals are covered with slightly larger arm motions than those used in scales.

While feedback of the kind described above would come in handy at the initial stages of learning, i.e., when action takes place slowly and when enough time is available for checking visually and individually the various points on such a list, aural and kinesthetic feedback becomes increasingly important when the movement is refined, noting the decrease in visible movement amplitude usually accompanying such refinement. The restricted usefulness of visual feedback furthermore becomes apparent when passages involving active participation of both the hands have to be mastered, as it is usually not possible to monitor both hands on an equally intensive basis.

Attention should be directed to the fact that Fleisher (Noyle 1987:98) in fact holds that much is to be gained from *eliminating* the visual feedback obtained by looking at the keyboard:

> You develop a kind of sense of touch, sensitivity of touch, like a blind person. You play by Braille, you begin to relate to the keyboard in a different way, and you discover that you learn to play with much greater accuracy, much greater physical precision. Another benefit is that one hears much more clearly what is happening ...

Vengerova (Schick 1982:62) even advised her students to practise leaps without looking; "[b]y doing this you learn to gauge the distance better utilizing your other senses".

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[15]Closely related to this topic is the field of observational learning, where the aim is to learn by watching another perform. This subject will be discussed in Section 5.2.2.2.

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Fleisher (Noyle 1987:98) furthermore points out that visual feedback could actually inhibit the more important functions of aural feedback. Pianists should constantly be

> ... judging, listening to what we're doing so that if what is coming out of the instrument is not what we originally planned, we can adjust what we're doing and get closer to our ideal. And that comes more quickly if one doesn't watch the keyboard.

3.2.2 Extrinsic feedback

Extrinsic feedback[16] is "feedback that is artificially added and is not a direct consequence of performing the movement" (Kerr 1982:308). Probably the most common manifestation of external feedback in the learning situation is the feedback given by the teacher to the student. Schmidt (1988b:425) defines five "pairs" of dimensions of extrinsic feedback which provides for a more accurate understanding of this type of feedback. These pairs are

- concurrent vs. terminal feedback
- immediate vs. delayed feedback
- verbal vs. nonverbal feedback
- accumulated vs. separate feedback
- knowledge of results (KR)[17] vs. knowledge of performance (KP)

Concurrent feedback can be distinguished from *terminal feedback* by the fact that the former is delivered during the movement task, while the latter is postponed until after the completion of the task. Temporally speaking, feedback can be delivered either *immediately* or following some time *delay*. *Verbal feedback* is "[p]resented in a form that is spoken or capable of being spoken" (Schmidt 1988b:425) while the opposite is true for *nonverbal feedback*. *Accumulated feedback* reflects "... the average performance for the past few seconds" (Schmidt 1988b:426), while *separate feedback* reports on each moment in the performance.

The important type of extrinsic feedback, termed *knowledge of results (KR)*, is defined by Schmidt (1988b:425) as "[v]erbalized (or verbalizable) post-response information about the outcome of the response in the environment". It should be emphasized that KR is *not* feedback about the movement itself, but rather feedback about the achievement of the goal.

Kerr (1982:77) notes that KR can be *intrinsic* as well, in the sense that goal achievement is evaluated by the performer himself through making use of aural feedback for instance, as was

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[16]Also sometimes referred to as *augmented feedback*, for example by Adams (1987).

[17]It should be pointed out that some authors, for example Adams (1987), use the term KR in a more general sense to include KP as well. Adams's (1987) equivalent for the term KR in the sense used by Schmidt is *outcome knowledge of results*.

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described previously: "[a]lthough KR can be either intrinsic or extrinsic, in most studies KR is referred to as an extrinsic source of feedback"; thus its inclusion under the present heading.

Contrary to KR, *knowledge of performance (KP)* is (Schmidt 1988b:425) "[v]erbalized (or verbalizable) post-response information about the nature of the movement pattern". KP is of particular importance for piano playing, as it would typically apply to aspects of the pianist's playing, he would, while engrossed in the intricacies of a difficult passage, only be "... vaguely aware of, such as the behavior of a particular limb in a complex movement" (Schmidt 1988b:426). As in the case of KR, KP can be intrinsic as well; an example mentioned earlier is visual feedback.

The difficulties of learning without KP when only KR is available, as is often the case, are explained by Adams (1987:62) as follows:

> ... the trainee must use the time between trials to draw inference about pertinent [movement] segments, segment weights, and segment errors in relation to goal error. That most performers attain only a modest level of performance for popular skills over a lifetime of practice is testimony to the difficulty of this inference process ...

Schmidt (1988b:452-453) points out that KR and KP, apart from being informational, can also be thought of as having *motivational*, *guidance* and *associational* functions. As regards the motivational aspect, "KR and KP make the task seem more interesting, keep the learner alert, result in the learner setting higher performance goals, and generally make boring tasks more enjoyable". KR and KP can also be regarded as "guiding factors" in the sense that they have an implicit "instructional" nature, specifying the modifications the corrected movement should incorporate. The associational function of KR and KP involves the use of feedback to establish rules or schema, a topic which will be examined in Section 3.4.2.

In the following sections the characteristics of extrinsic KR and KP will be examined in greater detail.

3.2.2.1 Temporal aspects of KR

This section of the present study is concerned with when it will be most beneficial for the learner to receive KR. According to Schmidt (1988b:454), trials without KR do contribute to learning, but not as much as when KR is given. Both the relative and absolute frequencies at which KR is given is important for learning. Of particular interest for the timing of KR, are three time intervals termed

- the KR delay
- the post-KR delay
- the intertrial interval

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The *KR delay* - termed the pre-KR interval by Kerr (1982), Adams (1987) - is "[t]he interval from the production of a movement to the presentation of KR" (Schmidt 1988b:455), the *post-KR delay* - or post-KR interval (Kerr 1982), (Adams 1987) - "[t]he interval of time from the presentation of KR to the production of the next response" (Schmidt 1988b:455), while the *intertrial interval* (or inter-response interval) can be defined as that period in time spanning both the KR delay and post-KR delay; thus "[t]he interval of time from one response to the next in the KR paradigm" (Schmidt 1988b:454).

Considering the various experimental findings on the influence of the length of the KR delay interval on motor learning, Schmidt (1988b:437) points out that"... we must question the relevance of the KR delay variable for motor learning in general". The KR delay interval should however not be filled with other movement activities that could be confused with the task movements, due to the fact that the subject apparently should

> ... retain in short-term memory the sensory consequences (the "feel") of the movement until the KR is presented, so that the two can be associated. (Schmidt 1988b:439)

Two procedures, both concerned with regulating opportunity for error processing, have been used by closed-loop theorists in studying the significance of the post-KR interval, namely (Adams 1987:60) "... to shorten or lengthen the interval, or to fill the interval with an activity that would either compete with the processing or not". It appears as if the learner in the post-KR delay interval will be actively planning a modified, more correct version of the relevant movement task - therefore, it is expected that systematically shortening the post-KR delay interval should at some point degrade learning, because the learner will not have enough time to prepare the modified response (Schmidt 1988b:440-1). Filling the post-KR delay with secondary task information-processing "... probably decrease performance and learning slightly", according to Schmidt (1988b:454). Increased complexity of KR was shown to affect performance in an adverse way, only when the post-KR interval was not long enough for necessary information-processing to take place (Adams 1987:60). Magill (1988), however, has produced experimental results that contradict this traditional position. His findings (Magill 1988:242) actually suggest that "... interfering with KR processing can actually benefit motor skill learning if learning is viewed as enabling the individual to successfully produce previously unpractised variations of a practised action". Adams (1987:60) notes that the inconclusive results of studies on information-processing in the post-KR interval could have been due to "... a failure to appreciate the speed of error processing in simple tasks".

Intertrial intervals, according to Schmidt (1988b:440), should not be made excessively short; it has been suggested that longer intertrial intervals cause the current solution to the relevant motor problem to "fade" in memory, thus requiring a vigorous effort on the next trial.

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Finally, Schmidt's warning (1988b:440) should be heeded that "... much more study is needed of these various intervals, using tasks of varying complexity, before we can claim to understand the processes at work".

3.2.2.2 Precision of KR

Schmidt (1988b:455) describes *precision of KR* as "[t]he level of accuracy with which KR describes the movement outcome produced". Error information can be presented with respect to *direction* and *magnitude* (Schmidt 1988b:447), for example "your wrist is held two inches too high with respect to the keyboard" if the hand position, instead of the sound produced, is seen as some sort of intermediate movement goal. For the present study, it is of interest only to note here that "[w]hile we might think that too much KR precision is harmful for adult learning, the evidence does not support this claim" (Schmidt 1988b:448).

3.2.2.3 Types of KP

Schmidt (1988b:448-451) singles out four types of feedback on performance as of particular importance, namely

- kinematic feedback
- kinetic feedback
- videotape replays
- biofeedback

Of immediate importance for the present study in view of its behavioural emphasis, are the first three types which will hence be discussed in greater detail.

(a) Kinematic feedback

The term *kinematic feedback* refers to "[f]eedback about the movement characteristics or movement pattern produced" without regard to the forces producing them (Schmidt 1988b:455,449). Kinematic feedback is probably one of the most common tools available to the music teacher in his instruction of piano-technical skills;

> [c]lever music ... instructors ... seem to be able to sense "what went wrong" and to provide verbal descriptors that can serve as suggestions for change. (Schmidt 1988b:449)

Most kinematic feedback focuses on information that, although not impossible for the subject to observe by himself, is unlikely or difficult to be effectively perceived during execution of the relevant movement pattern.

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It is not yet known which forms of kinematic feedback will be most useful to the subject under particular conditions (Schmidt 1988b:450). A reason for this lack in verifiable knowledge could be the traditional emphasis on (outcome) knowledge of results (Adams 1987:62); in the past, the bulk of KR research was concerned with "... movement outcome in relation to an environmental goal", with relatively little attention bestowed on "... refinement of a movement sequence required in getting to the goal" (Adams 1987:61).

At the present time, however, kinematic feedback is the main topic of research in the KP field. Adams (1987:61) regards this type of feedback as having to do with the shaping of movement sequences, a *movement sequence* being "... composed of segments, each of which contributes to outcome, that differ in weight and do not contribute equally to outcome" (Adams 1987:62). Of course, long movement sequences abound in piano playing. Adams (1987:61) lists three different methods of delivering kinematic feedback to the learner:

The *first* method involves showing the learner the pattern of his response sequence only. The learner himself must infer error in the pattern.

The *second* method, the advantages of which have been proven experimentally (Adams 1987:62), requires demonstration to the subject of the pattern of his response sequence along with the ideal pattern that he is to master. The difference between the two then is a measure of error which can be directly observed. It is redoubtable, however, whether such an approach would be effective where it counts in piano playing, because in high-speed, highly refined movements, individual motions of fingers are sometimes hardly visible.

According to Adams (1987:62), the *third* way is commonly employed in the performing arts. It involves giving the learner "... error information for some or all of the segments that make up the movement sequence. An instructor might point out several mistakes that the subject made as he or she advanced to the goal" (Adams 1981:61). The difficulty of learning can be greatly alleviated if the performer can be supplied with such segment KP in addition to KR because "... he or she will then have little left to figure out alone" (Adams 1987:62). It also appears as if identification of that particular segment in the movement sequence with the greatest relative weight, could contribute to facilitate the learning process;

> [t]he segment that was most heavily weighted is the big contributor to outcome knowledge of results, and a subject could easily infer that concentration on the segment would be the easiest way to reduce goal error.

The possible use of videotaped performances, which is a means of giving segment KP, will be discussed later in the present section.

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While the third method of giving kinematic KP appears to be quite familiar to the field of piano teaching, more research is undeniably required to determine which of these three methods will be most effective - under which particular circumstances - for the learning of piano-technical skills.

(b) Kinetic feedback

Kinetic feedback is "[f]eedback about the force characteristics of a movement" (Schmidt 1988b:455). The importance of kinetic feedback for piano playing can hardly be underestimated, especially as a common problem of piano technique is the exertion of excessive force to depress keys which essentially present little resistance. Generally speaking, however, this direction in motor learning research unfortunately appears to be underdeveloped as well; Schmidt (1988b:451) notes that "[t]he uses of this type of feedback about forces has the potential to be very effective for skills learning, and much more research effort could profitably be directed to this problem".

Prostakoff and Rosoff (1969:6) suggest that the teacher can supply kinetic feedback to the learner of piano technique by holding the hand, forearm or upper arm of the student during a pantomime or actual performance, sensing whether "... the coordination is right - whether the hands, for instance, are alert, too limp, or to eager (in relation to the upper arm) to get to the keys".

(c) Videotape replays

While the use of videotaped recordings of the subject's performance intuitively would be expected to be highly beneficial, according to Schmidt (1988b:449) "... little research evidence exists that this method of presenting KP is very effective"; this could probably be due to the fact that too much detailed information is presented to the subject, the latter not knowing which of the massive number of aspects to attend to. Directed viewing, in which subjects are shown which aspects to pay attention to, may however prove beneficial. As before, this matter requires some further investigation with respect to piano playing.

3.3 Stages of motor learning

Schmidt (1988b:460), following Fitts and Posner (1967:11-15), identifies three stages of motor learning which are respectively termed

- the cognitive phase
- the associative phase
- the autonomous phase

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In the *cognitive phase*, or *verbal-motor stage*, the learner is concerned with comprehending the task requirements and planning how the first trials can be accomplished - these are activities which demand considerable cognitive input. Because ineffective strategies are consciously replaced by better ones, "... the performance gains during this phase are dramatic and generally larger than at any other single period in the learning process" (Schmidt 1988b:460). Most of the improvements in this stage are linked to "*what to do* rather than ... the movement patterns themselves"; thus they could be considered "verbal-cognitive in nature". Practice in this phase is usually of a slow nature; "... we have to cajole ... [the mind], prove that the new pattern can be easy" (Slenczynska 1974:30).

The *associative phase*, which is sometimes termed the *motor stage*, can last for many days or weeks, beginning when the learner is ready to make adjustments of a more subtle nature in his movement patterns. The focus of attention now rests on the motor patterns themselves rather than what is to be done.

When the skill becomes automatic in the sense explained in Section 2.4.3.3 - i.e., automatic with respect to some specified secondary task (which is often of a verbal-cognitive nature), the *autonomous phase* of learning has been entered. Characteristic of this phase is that (Schmidt 1988b:461) "... the task can now be performed with less interference from many other simultaneous activities". As an example Schmidt, following Shaffer (1980), cites the concert pianist "... who can ... do mental arithmetic without interference while sight-reading and playing piano music". For the pianist, the benefits of this stage are of a rather more sublime nature: technically difficult passages can be executed "automatically", leaving information-processing facilities free to be devoted to interpretational aspects of the task, for example phrasing and dynamics. Therefore it is unfortunate that this highly important stage almost never is subjected to the scrutiny of researchers, simply because it could take months of commitment for test subjects to become sufficiently highly skilled in the motor task required for the experiment.

3.4 Two motor learning theories from motor systems theory

According to Schmidt (1988b:41), a theory is "[a]n abstract hypothetical explanation for a group of laws and facts", with a *law* being "[a] statement of a stable dependency between an independent variable and a dependent variable". A theory should be generally applicable in the sense that it should not be restricted to only particular tasks, or only a few experimental variables; in fact, "... a good theory of learning should, in a single structure, be able to explain as many ... laws as possible, and without contradicting any of them" (Schmidt 1988b:479).

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The two theories that will be presented in this section are associated with respectively J.A. Adams and R.A. Schmidt. By common agreement in the literature, both satisfy the requirements for fulfledged theories of motor learning[18], even though neither of them can explain all of the existing evidence on motor learning (Schmidt 1988b:490).

3.4.1 Closed-loop theory of Adams

3.4.1.1 Adams's closed-loop emphasis vs. the behaviouristic open-loop emphasis

According to Schmidt (1988b:479), the closed-loop theory of motor learning proposed by Adams in 1971 concentrated heavily on the learning of slow positioning movements;

> [h]e believed that the principles of performance and learning that applied to these responses were the same as for any other kind of response and that using a well-established set of empirical laws from positioning responses would produce a solid basis for theorizing.

Schmidt (1988b:490) sums up the essential workings of Adams's closed-loop theory as follows:

> ... the learner acquires a reference of correctness (called the *perceptual trace*) through practice and ... the improvements in motor responding result from the increased capability of the performer to use the reference in closed-loop control.

In contrast to Adams's theory stands the older open-loop model of learning, which can essentially be considered a learning representation

> ... in the traditions of ... behaviorism. If energizing agents like motivation and the habit strength developed by reinforcement (or knowledge of results) are sufficient, the response occurs, otherwise it does not; there is no appraisal of the response for correctness or an adjustment if it is wrong. (Adams 1987:58)

Although the behaviouristic theories made use of feedback in the sense of associating stimuli with responses - "[t]he response-produced stimuli of one response segment becomes connected to the next response segment as a way of explaining the learning of movement sequences", there was no question of error compensation following the measurement of the correctness of the response, and thus no feedback in the closed-loop sense.

3.4.1.2 Feedback

Two important feedback concepts, associated with Adams's closed-loop theory that also provide considerable insight into the structure of the theory, are

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[18]In order to keep the present study within manageable scope, less complete hypotheses - described by Schmidt (1988b:479) as "miniature theories", for instance the progression-regression hypothesis and hierarchical control models of learning, are excluded from these discussions.

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- the perceptual trace
- the memory trace

These concepts will now be explored more fully.

(a) Perceptual trace

The *perceptual trace*, an internal representation of sensory experience (Swinnen 1988:315), can be regarded as a reference of correctness that is obtained through practice with KR in the following manner (Adams 1987:58, Schmidt 1988b:480): on each trial in the repetition of a motor task, representations of the stimulus component of the feedback produced by the response (Schmidt 1988b:480)

... "leave a trace" in the central nervous system (hence the name perceptual trace).

The nature of this stimulus component can be visual and/or proprioceptive, for example. As each trial gets closer to the required response through use of knowledge of results, the imprinted representation of the feedback, or perceptual trace, becomes more and more alike to the feedback the correct response should have, until finally the perceptual trace represents the feedback qualities of the correct response.

It was pointed out earlier that Adams's theory is concerned mainly with slow positioning tasks. For such tasks, the perceptual trace represents the feedback of the correct position; employing the closed-loop procedure described in Section 2.7 for minimizing the difference between the perceptual trace and the feedback received, will thus result in the correct position for the relevant limb or limbs (Schmidt 1988b:479, Adams 1987:58).

It now becomes clear that the learner has two facilities for error detection and correction, namely knowledge of results and the perceptual trace. In this context, Adams (1987:59) describes knowledge of results as "... error information ... used in relation to the perceptual trace for making the next response different from the last one by having less error".

In fact, to Adams (1987:59) motor learning is essentially a perceptual process with cognitive characteristics as well, because "... knowledge of results and the correspondence between feedback and the perceptual trace, as sources of error information, combine to produce the trial-by-trial changes that constitute learning" (Adams 1987:58).

In order to explain how learners can develop capabilities for error-detection without external help, Adams proposed the idea of *subjective reinforcement*. In a learning setup associated with the latter concept, knowledge of results is omitted; the learner would compare feedback against the perceptual

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trace, using the difference representing the error as subjective reinforcement. However, this procedure can only occur provided that the perceptual trace is sufficiently strongly developed and that feedback from the response is strong enough. Also out of limits would be the initial stages of the learning process, because the subject at first does not know what the correct response should be, and therefore needs shaping of the response by an external source (Adams 1987:59).

An interesting implication of the theory of Adams is that errors made while training are detrimental to learning, because the feedback from the incorrect response is necessarily different from that of the correct response when errors are made, resulting in degrading the perceptual trace "... a little bit" (Schmidt 1988b:481). Thus the importance of error-preventing guidance in the process of training should be reckoned with in designing strategies for motor learning.

Regarding the above, Reubart's (1985:80) notion on the importance of first impressions also appears to be of some relevance:

> The first auditory and haptic impressions unquestionably register somewhere in long-term memory, and if they are correct registrations, they can be an advantage to memory in performances for years to come. This is as true of auditory memory as it is of haptic memory ...

(b) Memory trace

While the perceptual trace represents the perceptual nature of closed-loop learning, the *memory trace* is nonperceptual, and was devised in the context of the model presently being discussed to compensate for the fact that no feedback is available before the response appears, thus rendering the perceptual trace unusable. The memory trace is defined by Adams (1987:59) as "... a brief motor program that selects and initiates the response, preceding feedback and the use of the perceptual trace". It can therefore be said that the memory trace is used to get the movement started, after which the perceptual trace takes over.

3.4.1.3 Limitations of the theory

According to Adams (1987:60), two main points of criticism have been raised against the closed-loop learning theory - the one having to do with its theoretical construction and the other stating that additional concepts are needed to take into account certain experimental findings:

> (a) ... the theory relies too much on response-produced feedback and consequently fails to consider that movement sequences can be run off centrally without the aid of feedback ...
> (b) ... it fails to consider response variability, not of the random error kind but of the productive kind in which responding is flexibly adapted to a changing situation.

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In addition, Schmidt (1988b:481) points out some logical inconsistencies in the theory:

> Adams has the perceptual trace providing (a) the basis for placing the limb at the correct target location and (b) a basis for knowing how far that movement was away from the target location after the movement is completed.

But if the perceptual trace determines the positioning of the limb to the best of its "knowledge" at that particular moment, the same perceptual trace can not supply information about its own error with respect to the correct position.

Furthermore, Adams's theory does not take into account the very different uses of error detection mechanisms by slow and fast movements, and in fact can only be used to account for slow, linear-positioning responses. Schmidt (1988b:482) acknowledges the fact that Adams's closed-loop theory, at the time of its proposal, presented a major step forward in the field of motor learning due to the substantial research effort stimulated by it; however, it has been shown "... to have a number of limitations ... and it no longer accounts for the currently available evidence on motor learning".

3.4.2 Schema theory

A *schema* can be defined as "[a] rule, concept, or relationship formed on the basis of experience" (Schmidt 1988b:491). An example of a schema from everyday reading is the so-called "moral" of a story; the essence of the story can be termed the schema for the story, as opposed to the superficial details that is not fundamental to it (Schmidt 1988b:483).

Under the term *schema theory*, which is based on the rather old schema concept, is understood the theory introduced by Schmidt in 1975 to compensate for the shortcomings of the closed-loop theory listed previously (Schmidt 1988b:482). Relying on both generalized motor programs and the concept of schema, schema theory is distinguished from the theory of Adams in using (Adams 1987:60) "... response-produced feedback less than Adams's theory and [being a hypothetical construct] whose behavioral centerpiece is response versatility". Attractive aspects of Adams's theory, like the concern for slow movements, were however retained (Schmidt 1988b:482).

Schmidt (1988b:488) depicts schema theory as

> ... the theory that says we learn skills by learning *rules* about the functioning of our bodies, forming relationships between how our muscles are activated, what they actually do, and how those actions feel.

In subsequent sections schema theory will be investigated more closely for the purpose of identifying aspects that could be of avail in the process of acquiring piano-technical skills.

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3.4.2.1 Two states of memory: recall and recognition

According to schema theory, two states of memory exist for learning: the *recall memory*, which is responsible for movement production, and the *recognition memory*, which is responsible for evaluating the response from the movement[19].

Schmidt (1988b:483) describes the respective functioning of these memory states as follows: for rapid movements, recall memory "... is involved with the motor programs and parameters, structured in advance to carry out the movement with but minimal involvement from peripheral feedback", while recognition memory "... is a sensory system capable of evaluating the response-produced feedback after the movement is completed, thereby informing the subject about the amount and direction of errors". For slow movements, recall memory does not have much of a function, and for those slow movements that are not preprogrammed, the recall state, according to Schmidt (1988b:483), "... merely pushes the limb along in small bursts, with the individual stopping when the response-produced feedback and the reference of correctness match".

3.4.2.2 Two types of schema: recall and recognition

Inextricably intertwined with schema theory is the concept of the generalized motor program[20]. According to Schmidt (1988b:484), four "items" of information are stored following the performance of a movement by "running" its generalized motor program. These items are:

- the initial conditions regarding the limbs of the learner and the environment before the inception of the movement
- the parameters assigned to the generalized motor program
- KR as representative of the movement outcome
- the sensory consequences of the movement, i.e. "... how the movement felt, looked, sounded ..."

Storage of these items is sufficiently long for two types of relationships or schema to be formed between them, namely *recall schema* and *recognition schema*. Adams (1987:61) concisely describes the roles in motor learning of recall schema and recognition schema as follows:

> Recall schema selects the values of the movement parameters that specify the particular movement to be made from among those in the movement category, and the response recognition schema evaluates the correctness of the movement that is made. ... In a particular situation the recall schema reacts to the initial conditions that call for the movement and

[19]Compare with the logical inconsistency in Adams's theory described in Section 3.4.1.3.

[20]Although schema theory does not attempt to explain how motor programs originate.

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> specifies the parameters, and the response recognition schema is the reference against which feedback from the movement is evaluated for error.

Thus, with knowledge of results which aids in error detection and redefinition of parameters to compensate for error, experience also plays an important role in that stored information involving *inter alia* initial conditions, gained from previous trials, is required to launch the movement.

The concepts of recall and recognition schema will now be examined in greater detail.

(a) Recall schema

Recall schema, which is concerned with the production of movement, is described by Schmidt (1988b:491) as "... the relationship between past parameters, past initial conditions, and the movement outcomes produced by these combinations". These relationships are obtained through a series of trials with different parameters passed to the generalized motor program, resulting in different movement outcomes; following the execution of a sufficient number of trials, the learner begins to see a trend with respect to parameters and outcomes which eventually gives rise to the rule, or schema.

The way in which recall schema are developed, can be explained in a more graphical manner as follows (Schmidt 1988b:484): suppose the forming of rules or schema are represented by a two-dimensional graph[21] where the horizontal axis represents movement outcome and the vertical axis the individual parameters that are passed to the motor program each time the movement is executed. Any discrete point on the graph thus represents a certain parameter and movement outcome pair. When the generalized motor program is executed a sufficient number of times, i.e. when enough discrete points are available, the line of best fit, which

> ... perhaps ... [represents] the "direction" in which the "cloud" of points is oriented (Schmidt 1988b:304)

can be regarded as the rule relating input parameters to movement outcome. Every time the movement is executed anew, another point is added to the graph, which causes a slight modification to the rule -

> [a]fter each of these adjustments, the stored data are "thrown away," so all that remains of the movement is the rule ... [i.e.] the recall schema. (Schmidt 1988b:485)

Different initial conditions are each accounted for by data and a "line of best fit" of its own.

Actual use of schema occurs as follows: when the learner decides to carry out a movement pattern for which the generalized motor program has been run enough times to allow for schema

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[21]The graph representation is of a merely conceptual nature; no particular dimensions can be associated with the different axes.

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construction, the desired movement outcome in the environment and initial conditions regarding both environment and the bodily position of the learner are noted. Using the schema or rule that originated through past experience, that particular parameter can be selected which, on substitution in the generalized motor program, will yield the required response for the given set of initial conditions (Schmidt 1988b:485).

Taking into account the above arguments, the usefulness of recall schema is aptly summed up by Adams (1987:60) with regard to everyday motor activities as follows:

> ... recall ... schema is seen as a categorical concept that yields the ability to hit a tennis ball many different ways to the same place or, more simply, to take several behavioral routes in touching a desk corner.

(b) Recognition schema

Recognition schema can be described as (Schmidt 1988b:491) "... the relationship between past initial conditions, past movement outcomes, and the sensory consequences produced by these combinations". Used in a manner analogous to recall schema, the individual will select a movement outcome and determine the state of the initial conditions before performing the movement. Use of the recognition schema will then enable him to predict the sensory consequences of the movement; these expected sensory consequences can be regarded as analogous to Adams's perceptual trace that was discussed in Section 3.4.1.2.

3.4.2.3 Recall and recognition schema incorporated into the global organization for motor learning

In Figure 3.1 a flow diagram representation by Schmidt (1988b:487) is shown for the critical elements in a movement performance, accounting for both rapid and slow movements.

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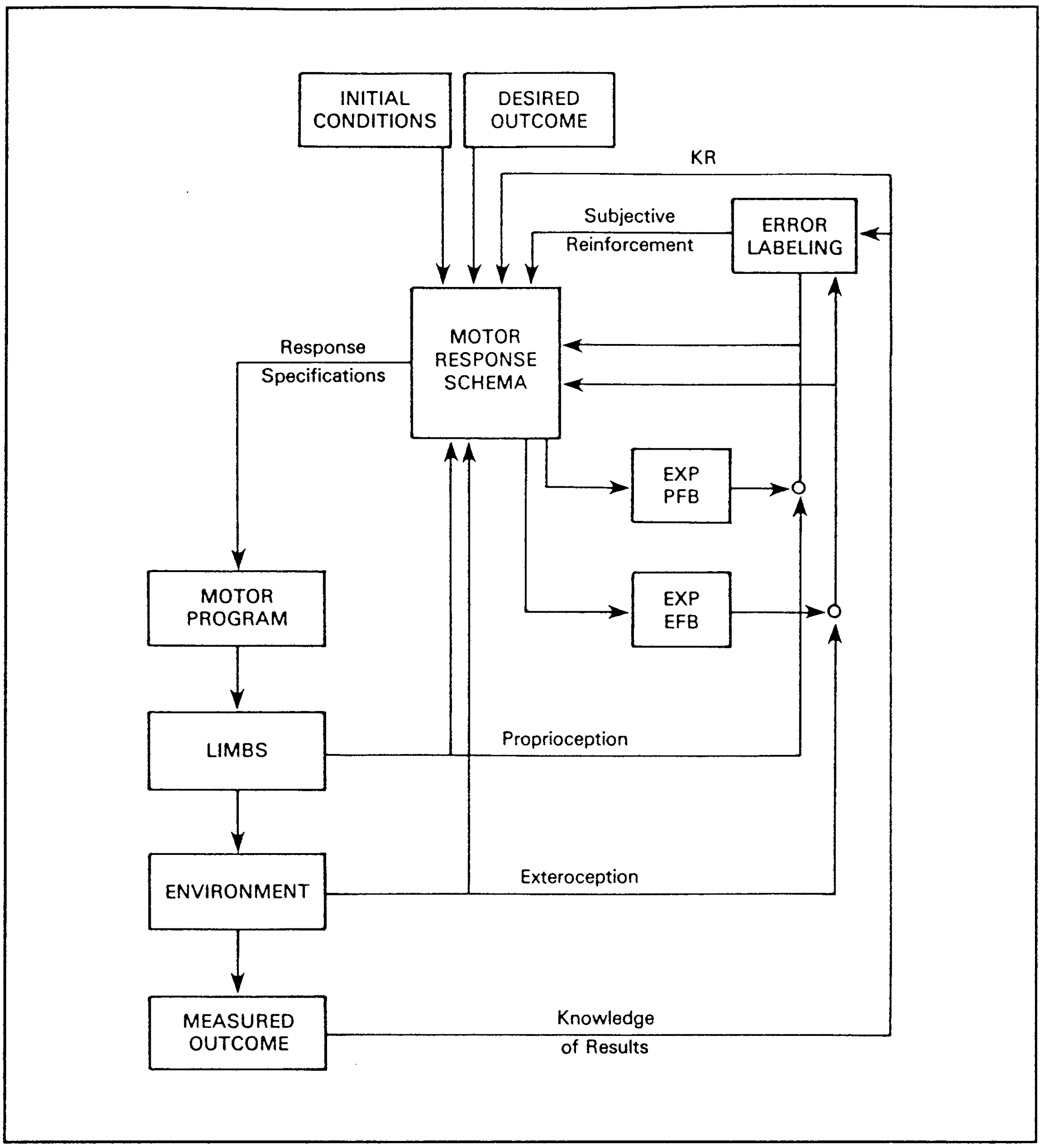

Figure 3.1 Flow diagram showing the schema theory point of view to critical elements in a movement performance (EXP PFB = expected proprioceptive feedback, EXP EFB = expected exteroceptive feedback). (Reproduced from Schmidt, 1988b:487)

For fast movements, the system receives input information about initial conditions and the required response, causing the system to point out the parameters for the general program and the expected sensory consequences in terms of, for example, proprioceptive feedback and exteroceptive[22] feedback. After execution of the motor program, the actual proprioceptive and exteroceptive feedback are compared to their respective expected states. Differences represent errors which, according to Schmidt (1988b:486-487), are delivered back to the information-processing stages, serving as

[22]*Exteroceptive feedback* consists of information about events outside one's own body (Schmidt 1988b:147).

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subjective reinforcement.

Subjective reinforcement is considered to be the prime factor in producing the movement patterns for slow movements (Schmidt 1988b:487):

> ... the expected feedback sources represent the criterion of correctness, and the feedback compared to them gives ongoing information about errors during the response. Then, the individual moves to a position such that the error is as small as possible, indicating that the individual's limbs are on target. Thus, even though the slow movement is actively produced, it is thought to be governed by recognition memory and the recognition schema.

It is not clear at the present stage how knowledge of the rather elaborate model of learning represented in Figure 3.1 can aid the learner of piano playing; more research in this regard is clearly required.

3.4.2.4 Variable practice

Schema theory supposes that practising a variety of movement outcomes with the same program will lead to more widely spaced points on the "graph" for schema development described in Section 3.4.2.2, resulting in greater certainty as far as the characteristics of the "line of best fit" is concerned[23]. Thus, "... varied training would produce the best performance in transfer" (Adams 1987:61); experimentation to verify this prediction has produced "... findings [that] are mixed, but tend to be positive". These positive signs have been found to be stronger with children; a possible reason for this phenomenon, according to Schmidt and confirmed by Adams (1987:61), is that "... adults have had so much varied training in their extraexperimental lives that the varied training they receive in the laboratory adds little to the capabilities they already have".

3.4.2.5 Motor learning may be primarily rule learning and not learning of responses

Experimental findings involving open skill motor tasks in particular, have shown that learners who have been subjected to varied training, can produce novel responses almost as accurately at the first attempt as they would have been produced after repeated practice, suggesting that "... motor learning may be primarily rule learning and not the learning of specific responses" (Schmidt 1988b:488).

[23]But see also Section 5.3.5.

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3.4.2.6 Limitations of the theory

A major limitation of schema theory - in particular with respect to the action viewpoint - is its emphasis on the generalized motor program (Adams 1987:61); while Schmidt (1988b:489) stresses the fact that he believes in the generalized program idea, he nevertheless states that

> ... the entire structure is vague in terms of how the program is formed in the first place, how the rules about parameters and sensory consequences are developed and used, how the individual makes the first response before any schema can exist ... [I]f the generalized motor program idea might later be shown to be incorrect, so too will be schema theory, as the theory depends strongly on it.

The other problem with schema theory arises in the laboratory. It goes without saying that a theory of learning should be able to account for findings in laboratory experiments involving motor skill research, because theories are supposed to be backed by experimental evidence, and in some cases even originate from such evidence. Due to the way in which schema are formed, they can be regarded as rather stable rules which could take years to establish. To explain the motor learning that occurs in laboratory experiments, schema are required to change rather drastically between trials, in order to account for the more effective choosing of generalized motor program parameters that is associated with an increase in learning. This notion of radical changes in schema is not compatible with the stable-rule character of schema (Schmidt 1988b:489), presenting a serious problem for the theory.

While schema theory does offer some marked improvements over the closed-loop theory of Adams, Schmidt (1988b:489) unequivocally states that the theory does not offer a complete understanding of the experimental findings on motor learning; in fact, "[s]ome logical problems need to be solved, and it is not clear that this can be done without discarding the entire theoretical structure".

3.4.2.7 Application of schema theory to musical instrument performance

Owen's (1988) concept of schema theory is rather different from that of Schmidt in that it is based on a hierarchical control model of learning, which is considered by Schmidt to be one of the less complete hypotheses of learning, i.e. not a fulfledged theory in the sense of the theories of Adams and Schmidt. For the sake of completeness and in view of the lack of research pertaining to musical instrument learning on this matter, some discussion will nevertheless be devoted to Owen's work. It is of course hoped that Owen's findings, which only pertain to orchestral and band instruments, will have some relevance for piano playing as well; some more research is however required before any conclusive statements can be made in this regard.

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Based on the interpretation of schema by LaBerge, Owen (1988:1-4) holds that schema are a fairly small set of rather abstract concepts of movement patterns stored at an executive memory level. A second memory level, called coordinative structures, store the needed information to turn the general concepts from the executive level into real and specific movements. The coordinative structures obtain their information by effectively getting programmed with specific muscle movements when a new skill is learned.

Scale learning and performance can in this context be explained as follows (Owen 1988:3):

> In the early stages, the scale is learned a single note at a time, along with its fingering. Eventually, the notes become linked together in a more abstract form which could simply be called "scale" [i.e., the schema]. When an experienced performer encounters the scale in printed music, the executive level may furnish the abstract concept of scale to the coordinative structures, where the specific set of movements necessary to perform the scale have been stored. It is not necessary for the performer to think of the notes of the scale individually and how to produce them, since that information is stored at a different level.

It is of some interest to note Owen's (1988:31) view that schema theory influences perceptual learning as well; the latter topic is however not a matter for consideration in the present study.

Instruction based on motor schema theory was found by Owen (1988) to have produced significant improvements in practice techniques for undergraduate performers in brass, woodwinds, and stringed instruments. Of the three test groups - which included the control group which received no instruction on practice techniques, the second group which received instruction on "traditionally" accepted methods of practice, and the third which was supplied with both applied practice techniques and techniques based on applications of motor schema theory, the motor schema theory group at their own initiative practised more than the others, and also reported "more favourable feelings" concerning the formation of goals, the practice strategies used and the balance of mental and physical practice (Owen 1988:81-82).

The conclusions reached by Owen (1988:8283), based on a statistical analysis of his data, which are the most relevant for the present study, are listed here:

1. Motor schema theory of learning is valid in teaching of practice strategy.
2. Differences apparent at the conclusion of the experiment were due to combined effects of instruction, rather than individual components of the instruction.
3. Understanding of motor schema theory concepts takes relatively long.

Hong (1989:82-83), however, "question[s] the internal validity of the resultant data" on a number of grounds, including uncertainty about whether the traditional practice group and the motor schema group actually *did* use these techniques as discussed by the researcher. Other questions that remained unaccounted for in the experiment were; the practice techniques employed by the test subjects before

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the experiment; whether the results would have been different if participants had been grouped according to the year of study; and whether "individual aesthetic sensitivity and kinesthetic response of subjects result[ed] in suspect data ...".

It is nevertheless worthwhile to reproduce here some of Owen's (1988:84 ff.) suggestions on musical instrument practice based on his concept of motor schema theory. More research is needed to determine whether these considerations are indeed valid for piano practice as well; no apparent reasons exist, however, for regarding them as particularly inappropriate to piano playing.

With respect to the coordinative levels of control, Owen (1988:84-85) suggests that the learner should "[b]uild from smaller to larger units" in the acquisition phase of learning, connecting these smaller units into progressively larger ones: "[f]or example, individual notes could be linked into a scale, or a number of motives could be linked into a phrase". Errors should be avoided due to their detrimental effect on schema forming. In order to promote the development of "varied" schema, attempts should be made to practice as many links between musical units as possible:

> Students might practice from the middle of one phrase to the middle of another, build the phrase from the end backward to the beginning by practicing one measure at a time, or locate boundaries in the playing when stops occur, or where errors occur.

According to Owen (1988:85), the executive level can be developed during practice by trying to relate the material currently being practised to material practised before, for example by recognizing familiar movement patterns. A passage consisting of a number of different scales, for example, may be related to scale patterns learned previously, which will help "... a new image [to] be formed, and stored at the executive level in a general way" (Owen 1988:86). Efforts should be made to constantly cultivate larger, more extensive schema, for instance by linking subsidiary phrases of a section together, or by linking smaller units such as scales and chords together in more sizable segments.

3.5 Motor retention and memory

Vague descriptions of "finger memory" and the other types of memory involved in piano playing abound in the literature on piano technique, a typical example being Neuhaus's (1973:147) distinction between two types of memory, namely "... the musical (spiritual) and the muscular (bodily)" memories. The purpose of the present section is to investigate the concepts of motor memory and retention from the motor behaviour science viewpoint, with particular emphasis on their description in terms of man/machine characteristics.

Retention is defined by Kerr (1982:312) as "the persistence of a skill over a period of no

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practice". Schmidt (1988b:512) describes *motor memory* as "... the persistence of the acquired capability for responding"; therefore, memory can be distinguished from learning in that the latter has to do with the acquisition of certain skills, while the former is concerned with maintaining these skills over a period of time. Losses in memory are termed *forgetting*.

Schmidt (1988b:493-494) emphasizes that, contrary to the notion held in some branches of psychology that memory is synonymous to a place where information is stored, motor memory should rather be seen as the *capability* for responding; thus, "[d]epending on one's theoretical orientation about motor learning, motor memory could be a motor program, a reference of correctness, or a schema that was acquired during practice".

While memory and forgetting are theoretical constructs in the field of motor learning, *retention* is a behavioural concept indicating persistence or lack of persistence in performance. According to Schmidt (1988b:494), "[i]t is the test that tells me whether or not memory has been lost", i.e. a decrease in performance proficiency after some retention interval could indicate that loss of memory has occurred, provided that the usual factors affecting performance, like fatigue, are accounted for.

Contrary to the situation in the field of verbal learning, mechanisms for forgetting in motor learning have not been studied intensively, and thus are not well understood.

3.5.1 On theories of forgetting

While most of the theoretical work on forgetting in the literature pertains to verbal learning, Schmidt (1988b:497) singles out two theories that may be of interest to motor forgetting, namely

- the trace-decay theory
- interference theory

The *trace-decay theory*, which is the oldest theory of forgetting, simply holds that information is forgotten because it is not practised, the forgetting process manifesting itself in a "decay" of the information with time. While the theory is based on little more than intuitive hunches, it accounts well for the effects of disuse and the passage of time on retention (Schmidt 1988b:497).

Interference theories of forgetting state that memory is degraded by the occurrence of other events that intervene between the learning of a response and its retention.

Two fundamental types of interference are distinguished, namely *retroactive interference* and *proactive interference*. Retroactive interference, which can also be regarded as a form of negative

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transfer, is (Schmidt 1988b:513) "... a source of forgetting caused by learning imposed between the original learning and the retention test for a to-be-remembered task", while in proactive interference forgetting is induced by some event occurring *before* the first learning of the to-be-remembered task. This event occurring beforehand could be, for instance, a skill learned through a lifetime of movement behaviour which inhibit learning of a new, different skill.

Schmidt (1988b:499) points out that, while scientists involved in verbal research are in general convinced that the bulk, if not all, of forgetting is due to either retroactive or proactive interference, experimental *support* for the interference theory does not necessarily prove that it is correct. Neither has sufficient focus been aimed at retroactive or proactive interference with respect to motor skills to contribute significantly to an understanding of motor forgetting.

3.5.2 Long-term motor memory

It has been pointed out previously that piano playing displays both continuous and discrete skill characteristics. In the present section, therefore, some brief remarks will be made on these skills with respect to their retention characteristics over long retention periods, i.e. weeks or months.

Continuous skills are extremely well retained over long periods of retention, which could add up to years of no practice. Examples from everyday life of such skills are swimming and riding a bicycle. Discrete tasks, on the other hand, are much more easily forgotten. The reason for this discrepancy is not clear; according to Schmidt (1988b:512), "[p]erhaps the difference is based on the idea that continuous tasks, with more practice time in a typical experiment, have more resistance to forgetting because they are learned more completely".

The fact that motor skills are generally well retained, can perhaps be explained by noting that motor skills are very specific, even to the extent that skills apparently much alike visually, could in fact have little in common. Thus it seems relatively unlikely that a skill in the process of being learned, will suffer from interference due to elements in common with other skills learned previously, implying that the learning process will proceed unhindered (Schmidt 1988b:503).

3.5.3 Short-term motor memory

According to Schmidt (1988b:512-513), an active research interest was maintained in this subject in the 1970's. Research efforts, apparently not of much interest for piano playing, were concentrated *inter alia* at once-presented movements and linear-positioning tasks, showing "... rather rapid

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retention losses, increased retention loss as the retention interval is increased to about 60 sec., and decreased losses as the experience at the target is increased".

It has been pointed out in Section 2.3.2 that the conceptual distinction between long-term and short-term motor memory is not regarded as of much significance at the present time. Apart from many experimental design problems preventing the clarification of short-term motor memory, Schmidt (1988b:508) states that

> [s]uspicion grew that much of the motor short-term memory paradigm was not motor at all, but rather was concerned with the retention of sensory information about the feedback associated with the target position.[24]

Thus Schmidt (1988b:508) depicts the current status of the concept of short-term motor memory as a matter of merely academic interest, the "rise and fall" of which the "educated student of motor behavior should know something".

3.5.4 Warm-up decrement

In conclusion to the section of the present study dealing with retention and motor memory, it is worthwhile to direct some attention to the phenomenon of *warm-up decrement*, which is described by Schmidt (1988b:513) as "... a retention loss caused by the imposition of a short rest in a series of practice trials". Experimental findings point to the *set hypothesis* as the most probable explanation for this phenomenon. This view holds that (Schmidt 1988b:509)

> ... the loss of skill is related to the loss of some temporary internal state(s), or *set*, that underlies and supports the skill in question. ... [M]emory of the skill is not lost over the rest period; or perhaps very small memory losses do occur, but they are far too small to account for the large decrements seen.

Although severe, the decrement is usually short-lived, and it is usually removed relatively quickly through practice.

Warm-up decrement is relevant in particular for high-level performance activities, where activities are either interrupted by rest, or major changes in the nature of the task takes place. Perhaps the most obvious example from the field of piano playing is that of performing a concert in public. Short rest periods occur between movements of works, and rather longer rest periods between the works themselves - the longest usually being the interval, while dramatic changes in the nature of motor activity could manifest themselves when a classical period work (a Mozart sonata), is followed by a virtuoso piece from the Romantic repertoire (a Liszt *Hungarian Rhapsody*).

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[24]The short-term motor memory paradigm is described by Schmidt (1988b:504-505). Due to the fact that neither it, nor the concept of short-term motor memory for that matter appears to be of particular relevance for the problems of piano playing, its discussion is omitted here.

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Whether the effects of warm-up decrement can be eliminated, would depend on the question whether performers can adjust their own sets of internal states. According to Schmidt (1988b:512), "[t]here is no evidence on this point, but it would seem so". In piano playing, it is possible that mental practice[25] could have a set-reinstating effect, while Schmidt does not rule out the possibility that "... these self-generated set-reinstating capabilities must be learned". In any event, finding solutions to the many unanswered questions in this area should hold considerable benefits for performers, "... because the decrements are particularly large".

3.6 Summary and conclusions

Intrinsic feedback is essential for motor learning in piano playing. But the use of intrinsic feedback itself requires some learning, as the student has to be taught purposefully to deploy his facilities for intrinsic feedback to their fullest extent. One of the two most important types of intrinsic feedback in piano playing is aural feedback, which involves the pianist's capability for self-hearing. Listening to oneself is a process involving various subtleties; more often than not pianists only hear what they expect to hear. Probably of equal importance is kinesthetic feedback, which involves the monitoring of sensations in the muscular playing apparatus. Visual feedback is only of restricted usefulness because of the smallness of the movement amplitudes involved in piano playing. Some authors are of the opinion that visual feedback should be relegated to only a minor role player in piano playing, or even eliminated as far as possible, in order not to interfere with aural and kinesthetic feedback.

Knowledge of results and knowledge of performance, whether given by a teacher or inferred by the learner himself, are fundamental components of the learning process.

The timing of the giving of extrinsic knowledge of results was investigated with respect to the completion of the current trial and the beginning of the next trial. Apparently, the precise amount of time that lapses during training from completion of the trial to the giving of KR (or KP) is not of critical importance. It is however recommended that this interval should not be filled with other movement activities in order to enable the learner to retain the "feel" of the movement until its KR is given. The post-KR interval should be long enough for the next movement to be planned; contrary to expectations, it was found that filling this interval with secondary information-processing activities could strengthen the ability of the learner to produce *impromptu* variations on a previously learned motor task. Further research is necessary, both to obtain more conclusive information on the significance of the KR delay and post-KR delay for learning, and to determine how these results relate to piano-technical learning.

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[25]This topic will be examined in Section 5.5.

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Kinematic feedback, kinetic feedback and videotape replays were identified as means for supplying extrinsic KP to the learner. While all three methods apparently are in use in the field of piano teaching, more research is required to determine their relative effectiveness as well as the circumstances under which they deliver optimal results. It appears as if information with respect to errors in the movement segments that comprise a movement sequence in piano playing, as well as identification of the segment with the largest relative weight, can be of considerable use in reducing goal error through kinematic KP; this suggestion however stands in need of experimental verification. The field of kinetic KP in motor behaviour science - and consequently in piano playing - appears to be under-researched as well. Few findings exist to support the effectiveness of videotape replays for general motor skill learning, the lack of effectiveness probably being due to the fact that learners are overwhelmed by the amount of information they are presented with.

The closed-loop theory of Adams was described. Unfortunately, its validity is limited to slow movements; Adams's premise that the principles underlying the learning of slow positioning movements are the same for any other types of response has proved to be incorrect. The failure of the theory to consider the possibility of the central control of fast movement sequences through motor programs, its lack of structures to account for response variability, and the logical inconsistency regarding the use of the perceptual trace for subjective reinforcement, makes Adams's theory an unlikely candidate to be used as a basis for learning of the richly-varied movement patterns required in playing the piano.

Schmidt's schema theory improves on Adams's theory in that it accounts for centrally-driven, rapid responses through the generalized motor program, as well as response variability by means of recall schema. Attractive features of Adams's theory, like the concern for slow movements and the concept of the perceptual trace - accounted for here by the recognition schema concept - are retained. Experimental findings on schema theory's premise that variable practice will produce the best results in motor learning tend to be positive. The great accuracy with which learners subjected to variable practice before can sometimes produce novel responses, has lead followers of the theory to believe that motor learning may be primarily the learning of rules (schema) and not responses. Practical experience from piano playing tends to support this notion: if a pianist has practised ten different major scales for some time, it is hardly likely that he will have excessive trouble mastering an eleventh. A major limitation of the theory is its heavy reliance on the concept of the generalized motor program. Also, the radical changes expected of schema to account for laboratory learning seem to contradict the stable nature assigned to them by the theory. It is not clear how knowledge of a schema model of motor learning, which can be rather elaborate, can aid the learner of piano technique; more research is clearly needed to clarify this matter.

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A less sophisticated version of schema theory which is based on a hierarchical control model for learning was briefly described. While empirical research findings, directed at whether practice methods based on this version of schema theory improve effectiveness in musical instrument practice, are available, it was not shown beyond doubt that the increases in learning that was observed, can indeed be attributed to the schema theory influences.

It was pointed out that, contrary to the situation in the field of verbal learning, the processes of forgetting in motor learning are not well understood. Continuous skills are usually extremely well retained over long periods of no practice, while discrete skills are more easily forgotten - more research is necessary to determine whether these findings hold for piano playing as well, which of course can have both continuous and discrete components. It was pointed out that, apparently, the concept of short-term memory is currently held to be of little more significance than mere academic curiosity. Warm-up decrement was found to be a phenomenon that is to be reckoned with especially by pianists performing in public; insufficient research findings were available to serve as a basis for valid suggestions on the minimization of its effects.

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CHAPTER 4

THE ACTION SYSTEMS APPROACH TO MOTOR CONTROL AND LEARNING WITH SPECIAL REFERENCE TO PIANO TECHNIQUE

4.1 Introduction

Action can be described as "... goal-oriented motor behavior" (Adams 1987:66).

Reed (1988:46) defines *action systems theory*[1] as resembling

> ... that [functionally based] area of motor skill research that emphasizes task orientation and offers a taxonomy of acts based on goals ... but ... adds the assertion that evolution has resulted in a number of autonomous action systems which work in their own way to achieve specific functions.

Although the difference between *motor systems theory* - "... the 'classical' and 'established' one in the motor domain" (Van Wieringen 1988:88) - and *action systems theory* is not altogether clear, a broad concept of the difference between the two can be gathered from the following descriptions:

> Motor systems theories ... may be loosely described as information processing theories making use of constructs like 'programmes', 'schemata', 'memories', 'images' ... Action systems theories, on the other hand, dismiss the former approach as an incorrect application of the computer metaphor to biological organisms. Instead, the complementarity and reciprocity between the organism and its environment is drawn to the foreground, and attempts to explain behaviour do justice to this intimate and non-contingent relationship.

Action theorists, for example Reed (1982:98-99), reject the psychological dichotomy consisting of the peripheralist (closed-loop) versus centralist (motor programming or open-loop) theories of motor control. It has been pointed out earlier that some theorists, for example Schmidt (1988b) and MacKenzie (1988), hold that motor behaviour is probably best represented by a hybrid of the two

[1] For the sake of convenience, this definition (which was given in Section 1.3) is reproduced here again.

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approaches. A major cause for this viewpoint is the fact that the closed-loop model is only satisfactory as far as relatively slow, highly accurate movements are concerned, while the centralist model is employed to account for fast motor responses. Reed (1982), however, points out that all such arguments, which at a superficial level have much to offer, are hampered by the common inconsistency that afference is assumed to be sensory feedback and efference assumed to be motor output from central control[2]; thus "... it would be better to make a clean break with these traditional but incorrect ideas and start over in conceptualizing action" (Reed 1982:107).

Closely associated with action systems theory is the *ecological* perspective to movement, which is depicted by Schmidt (1988b:16) as "... emphasizing the study of movement in natural environments, and the evolution of physical and biological constraints of movement". An ecological approach to music could be particularly appropriate on the grounds of the following statement by Clynes (1982:vii):[3]

> Music is one of man's most remarkable inventions - though possibly it may not be his invention at all: like his capacity for language his capacity for music may be a naturally evolved biologic function. All cultures and societies have music.

Schmidt (1988a:5) differentiates as follows between the newer *ecological psychology*[4] and the long-established field of *cognitive psychology*:

> ... cognitive psychology ... [has] made extensive use of internal representations, cognitive structures, and sometimes even anthropomorphic explanations of behaviour in an attempt to theorize about complex mental events ... . The neo-Gibsonians argue that this style of explanation does not provide an adequate answer, essentially because the nature of these representations ... themselves must be explained, which simply puts off the ultimate problem until some later time. Instead, this group has attempted to discover how much order and regularity one can have by assuming no representations (or, at most, minimal representations), using a number of fundamental organizing principles.[5,6]

The latter approach holds that representations of motor processes can always be added at a later stage, if required, instead of stating them beforehand, as some cognitive theorists seem to do.

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[2]Kerr (1982:305) describes *afferent pathways* as "the peripheral nerve pathways that bring sensory information into the brain via the spinal chord" and *efferent pathways* as "the peripheral nerve pathways by which motor responses are carried from the brain to the skeletal musculature".

[3]It is however not clear from the context whether Clynes intends his statement to include in particular the motor aspects of music as well.

[4]Schmidt (1988a:4) notes that the field of ecological psychology "... is very broad and comprehensive, attempting to deal in a consistent way with such diverse issues as perception, motor control, ecological and evolutionary perspectives, growth and development, and numerous other ... areas, only a small part of which is immediately relevant to motor control".

[5]The word *anthropomorphic* refers to having human form or human characteristics.

[6]It is possible to differentiate between two streams of thought in action systems theory, namely the Gibsonian and neo-Gibsonian schools (Van Wieringen 1988:87). The Gibsonians try to explain the motor behaviour as a function of information specifying the environment, while the neo-Gibsonians resort to physical principles guiding the behaviour of energy-consuming open biological systems.

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The origins of action systems theory can be traced back to a desire to develop an ecologically based taxonomy of *all* movements - not just skills (Reed 1988:46);

> [i]t begins with the hypothesis that there are many *different* action systems, each evolved by natural selection to facilitate a unique behavioural function, and therefore each with its own principles of organization ...

Psychologists, physiologists and engineers have all tried to identify and single out basic movement units as a means to effect a better understanding of motor control. In action systems theory, however, these units "... are defined *ecologically*, not biomechanically, anatomically, or physically" (Reed 1988:47). Action theorists furthermore claim that the elementary units of action are themselves functional, and that "... bodily displacements are a consequence of, not constituents of, actions" (Reed 1988:46). Although Reed does not deny the existence - which can be proved by laboratory experiment - of neurobehavioural[7] units, he does not recognize "... the *theory* that functional actions must be constructed out of such purely mechanically specific units".

According to action systems theory, human action in broad terms is structured as follows from its subsidiary components (Reed 1988:47): at the highest level of analysis, the principal constructs are *action systems*, which are comprised of *action cycles*, each of which in turn consists of "... *postures* and *movements* relevant to the task of that system [italics added]". Usually, several action systems are functioning simultaneously, "... the competition and coordination among action systems giving rise to a number of *basic actions* in each system".

The concepts mentioned above, and their relationship to each other, will be discussed more extensively in Section 4.2. The action approach to motor learning - a subject on which relatively little information seems to be available - will be investigated in Section 4.3, followed by some general conclusions in Section 4.4, specific reference being made to the control and learning of motor skills pertaining to piano technique.

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[7]According to Lee (1984:143), quoted by Reed (1988:46), a neurobehavioural unit can be identified as follows: "... if a pattern remains coherent even when reorganization would be functionally useful, then one can infer that it is a basic neurobehavioral unit".

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4.2 The action systems approach to motor control

4.2.1 Degrees of freedom as a common point of departure for the action and motor viewpoints

Before attempting to unravel some of the intricacies of the action approach to motor control, it is worthwhile to first of all explore some of the common grounds held with the motor systems approach discussed earlier.

In particular, Bernstein's (1984) conception of the motor system, which is considered by Schmidt (1988a:6) to be "... a cornerstone of the action view... and often of the motor view, it must be added...", deserves some attention. According to the view of Bernstein, the motor system is comprised of a great number of degrees of freedom which must somehow be controlled by the organism. Thus, movement can be studied at different levels of analysis depending on the number of degrees of freedom. Various possibilities exist in turn for determining the number of degrees of freedom, for example by

> ... counting the number of degrees of freedom in the particular joints (the elbow has one, the wrist two ...), by counting the number of muscles which act at the various joints ..., or even by considering the massive number of single motor units which must ultimately be organized in skilled actions (a given muscle may have several thousand motor units). (Schmidt 1988a:6)

In view of this approach to the motor system, Schmidt (1988a:6) identifies as the common goal for both motor and action theorists the

> ... search for ways that the various degrees of freedom are *constrained*, or coupled to one another, so that the control of a number of degrees of freedom is handled as a single unit, itself with only one degree of freedom.

While motor theorists use the motor programming idea for this purpose, the action systems view utilizes the concept of a *synergy*, or *coordinative structure*, which can be defined (Schmidt 1988a:6) as "... a group of muscles and joints acting together as a unit". Although Schmidt (1988a:6) states that he is not sure whether "... at a behavioural level of analysis, one can meaningfully distinguish between coordinative structures and motor programmes", at the level of neural control action theorists emphatically deny the existence of motor programs for constraining the various degrees of freedom.[8]

[8]As was pointed out in Section 2.9.

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4.2.2 Actions vs. movements

Fundamental to Reed's (1982,1988) thesis on action systems theory lies the conceptual distinction between *actions* and *movements*.

According to Reed (1988:48), *actions* can, due to their goal-directedness, be categorized either functionally, or in terms of their interaction with the environment. *Movements*, on the other hand, are traditionally categorized along the following widely accepted lines:

1. *Kinematically*, that is in terms of displacement of the limbs and torso seen with respect to some arbitrary point of reference.[9]
2. *Kinesiologically*, "... as displacements with respect to standardized anatomical axis (e.g., flexion-extension, pronation-supination ...)".
3. *Dynamically*, i.e. in terms of the forces that are responsible for the displacements.

Movements can, however, *not* be defined functionally or environmentally due to the fact that any one movement may be a subsidiary constituent part to many different actions.

While convention thus holds that movements are limb displacements of some sort and that movement control, therefore, is control of the "... coordinates of the body in space and time" (Reed 1988:48), Reed's (1988:51) fundamental hypothesis is that "... an action is made up of whatever displacements suffice to realize the agent's goal. What matters is not the displacements in space-time, but the movements and postures in the environment". Phrased alternatively, Reed (1988:49) proposes that

> ... animals and people achieve their goals not by moving their muscles, nor even by displacing their limbs and bodies, but by coordinating a series of subsidiary actions. Any action is therefore seen as made up not of mechanically specific displacements, but of functionally specific components *which themselves would count as actions.*

Two classes of functionally specific components of action are identified by Reed (1988:49), namely

- postures
- movements[10]

These components will be examined more closely in the following sections.

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[9]This method of description was pointed out in Section 2.2.1.

[10]Reed's notion of movement in the context of action should not be confused with movement in the "traditional" sense described earlier in this section and in Chapter 2.

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4.2.2.1 Postures

Postures should be regarded as the orientation components of an action, having to do with the actor's attempt to maintain a relatively persistent orientation of himself and his perceptual systems to the environment, the ultimate balancing act for humans being "... to maintain an upright posture while breathing, which changes the shape of the chest and disbalances the trunk above the hips and the head above the trunk" (Reed 1988:60-61). Thus, "[a] posture is an action in its own right, a persistent achievement of an organism in the environment" (Reed 1988:52). The action of maintaining an upright posture is *functionally* defined by Reed (1988:61) as "... any set of displacements of the musculo-skeletal system that serves to keep the head orientated to the environment above the neck and trunk [italics omitted]". Displacements in space - or the lack thereof - can not be used to (uniquely) define the upright stance, simply because "... *any* such displacements will do, so long as the above functional requirement is met".

4.2.2.2 Movements

Movements can be considered as subsidiary actions representing changes in the orientation components of higher level actions. In particular, movements are "... specific changes in posture that are organized by agents while effecting particular changes in the relation between the organism and the environment" (Reed 1988:52). The action understanding of movement is perhaps best illustrated through Reed's (1988:49-51) description of a baseball player engaged in the motor task of catching a ball:

> This act is not made up of some fixed sequence of displacements (these would vary indefinitely, depending on the ball's trajectory, the player's initial position, state of alertness, and so on). Rather, a successful catch involves orienting oneself to gravity, the playing field, and the course of play, orienting one's perceptual systems to the opposing hitters and the ball's motion ... and changing one's orientation so as to meet the ball with one's glove. The well prepared player can thus catch a ball without *any* displacement of the hands whatsoever, if the batter hits a line drive to the expected spot - yet surely this non-displacement would count as a highly skilled action!

On noting that postures can be defined functionally in an environmental sense, it follows that movements should be *functionally nested* changes of posture (Reed 1988:61) - "... in addition to serving its own function (whatever that might be) a movement must not be disfunctional with respect to ongoing postures". Thus, riding a bicycle should not interfere with the function of maintaining a stable head and unrestricted visual facilities; in humans speech does not interfere with the respiratory functions. Postural precedence effects[11], i.e. postural adjustments to amend for movements, are

[11]This subject will be subjected to further scrutiny in Section 4.2.3.

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regarded by Reed (1988:62) as a means for the "... *maintenance* of postural *function* (which may or may not be directly related to balance) before, during, and after the movement", rather than a way to account for the disbalancing effects of the movement. Thus, postural precedence effects may be seen as "... evidence of neural mechanisms for *inserting movements into postural cycles*".

4.2.2.3 Posture as the principal catalyst in piano technique: the method of Taylor

Taylor (1979) proposed an approach to piano playing, based on the principles of the music educator Raymond Thiberge and the teacher F. Matthias Alexander, that advocates postural control as the main catalyst for all aspects of piano playing; in postural control, "... Taylor believes he has found the Gestalt that harmonizes all the separate motions and positions of piano playing into one simple, coordinated act" (Bridges 1985:53-54).

The benefits that the mastering of Taylor's approach apparently holds for the advanced pianist seem to be staggering[12]; proficiency in the application of his principles would imply that "[i]f we can play a work at sight, then we have no need to practise it" (Taylor 1979:72). It is interesting to compare comments made or implied with respect to the difficulty of Chopin's *Etude* Op. 10 No. 2 by established concert pianists on the one hand, and Taylor on the other hand. Thus Ian Hobson (Elder 1984:19) notes that this particular *Etude* "[i]n a way ... is the most difficult of all the [Chopin] etudes", and Peter Orth (Elder 1979:21) states that

> [y]ou have to examine every tie, eighth note ... You can't slough over things. For example, these thumb notes are here for a reason: they balance the other side of the hand. If you don't play them out, the piece doesn't do the hand much good.

Taylor (1979:78), however, declares that

> [t]his is one of the easiest concert studies in the repertoire; if it doesn't 'play itself' at the first reading, this is salutary proof that the necessary conditions of co-ordination [established by correct postural control] are missing.

(It is of course assumed that a proper mental conception of the piece has been established beforehand, i.e. the performer knows the notes, expressive indications, *et cetera*.)

Like Reed, Taylor (1979:22) apparently sees more to posture than meets the eye:

> (i) [p]osture includes not only 'position', but also the way in which the parts are maintained in position; (ii) [t]he human body is an indivisible entity, in which the behaviour of any single part is dependent on the relationship existing between all the parts.

Thus the inevitable result of a postural deficiency, which could manifest itself in for instance a stiff

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[12]Thus its inclusion in the present discussions.

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neck, is "... a reduction in one's capacity for co-ordination"[13] (Taylor 1979:23).

According to Taylor (1979:27), two basic, mutually exclusive, postural conditions exist, namely *expansion* and *contraction*. Taylor states that these conditions should actually be referred to by using the grammatical forms *contracting* and *expanding*, because of their dynamic (i.e. ongoing) nature; for purposes of description it is however convenient to assume that they are static. According to Taylor (1979:63), the "liberation of talent" is closely related to the improvement of posture, and the substitution of contracting postures by expanding ones.

The *expanding* posture[14], which serves to enhance coordination, causes

> ... the tendency ... to become longer and wider, as the joint surfaces separate away from each other. The head is well balanced on the neck, whose muscles are in minimum tension, the shoulders are loose and wide in relation to the back so that the arms tend to hang towards the front of the body, and there is no pronounced hollow in the small of the back caused by hypertension in the muscles of the dorsal vertebrae. (Taylor 1979:29)

Taylor even goes so far as to suggest that, "[w]ithout exception", the great instrumental and vocal performers[15] have in common the expanding posture. Bridges (1985:56) describes how he has observed from film material the way the pianist Arthur Rubinstein apparently applies the expanding posture:

> With each important technical gesture, a loud chord or an octave scale, Rubinstein moves his head "forward and up" and visibly lengthens his spine with the shoulders loose and dropped all the while.[16]

What makes this observation the more relevant is Schnabel's *verbatim* expression (Wolff 1972:24-25) of his view of piano playing as a form of musical speech:

> 'One speaks upward and forward', he said, 'and therefore one must not play downward and backward'.[17]

The *contracting* posture, on the other hand, which usually inhibits coordination, manifests itself in that a person tends to become (Taylor 1979:27) "... shorter and narrower, because the joint surfaces are drawn towards each other by opposing muscular tensions". Extreme consequences of the contracting posture could be neck tensions, rigid, pulled-back shoulders, prominent shoulder

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[13]Some of Taylor's views on coordination have been discussed in Section 2.8.5.1.

[14]Taylor (1979:64 ff.) supplies some guidelines of how the student of piano playing, by invariably using some guidance from a qualified teacher, can establish the expanding posture at the keyboard.

[15]Some of the great composer-pianists also seem to have advocated the expanding posture. Taylor (1979:75) quotes Chopin's statement that his *Etude* Op. 10 No. 1 was intended to widen the spread of the hand; which is, as Taylor interprets it, "... a natural result of the elimination of contracting tendencies".

[16]Bridges does however not neglect to mention at the same time that many pianists apparently do *not* exhibit the characteristics of the expanding posture, citing as an example the pianist Walter Gieseking.

[17]Schnabel did however not impose his way of playing on students who managed musical and technical control in a different manner (Wolff 1972:25).

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blades and "... a pronounced hollow in the small of the back" (Taylor 1979:28). Taylor (1979:27-28) proposes a simple but effective - and rather startling - experiment which can be used as a diagnostic tool for determining whether a person is indeed the unfortunate possessor of a contracting posture:

> Stand facing a wall at such a distance that when the arm is held out horizontally, with the palm of the hand facing the floor, the finger tips are just touching the wall. Flex the arm quickly at the elbow, bringing the back of the hand up to the shoulder, hold it firmly in this position for a moment, then return the arm to the horizontal position. If you have contracting tendencies, you will find that the fingers no longer touch the wall, the arm seeming to have shortened by as much as an inch or two. Imagine this condition existing throughout the entire body in a greater or lesser degree - such is the contracting posture.

The reason for the shortening of the arm, or all the joint surfaces involved being drawn closer with respect to each other, is that the extensors of the forearm do not relax at the same rate as that of the flexors contracting when the arm is bent at the elbow, thus resulting in the simultaneous contraction of opposing muscles. The same is found with respect to the muscles of the neck and shoulder, because the arm cannot shorten without involuntary contraction of these muscles, illustrating the fact that "[t]here is no such thing as purely localised muscular activity" (Taylor 1979:29).

If the hand is simply brought into playing position at the keyboard under the expanding postural condition, the result will be freedom in mobility at the elbow before playing commences - which will not be the case under the contracting condition, although the playing positions achieved via both means may appear the same. According to Taylor (1979:31-32), to perform under the expanding posture is like being a detached observer watching the playing apparatus executing the appropriate actions; this state is preferred over a state in which each movement is concentrated on individually. Suppleness is maintained in the fingers by actually relieving the fingers from their role as the main functionaries in piano playing (Taylor 1979:58):

> To preserve maximum suppleness in the fingers, on which co-ordination with the keyboard depends, we must remove from them the burden of being treated as active agents in the act of tone production and instead regard them solely as transmitters of our basic gesture of expansion.

Apparently, learning to establish the expanding posture is a slow and painstaking process requiring considerable perseverance; from Taylor's (1979:63-73) description it seems unlikely that a student would be able to manage without the guidance of a qualified teacher. Furthermore, feedback about the correct posture appears to be quite alien to the normal modes of KR and KP employed in the piano playing lesson, as can be deduced from the following "... anatomically implausible, but empirically valid" description of the expanding posture by Thiberge (Taylor 1979:63):

> ... once the segments of the bone structure ... [are] correctly organised, a pressure initiated by "a subtle gesture of leverage against the thigh" ... [can] be transmitted through them to the fingertips without any intervening contractions.

Taylor's approach still needs to be tested scientifically in almost all areas to determine *inter alia*

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whether it is really the expanding posture which causes improved coordination, and if the improvements induced by it are potentially equally dramatic for all students.

4.2.3 Postural precedence effects

When a person voluntarily moves a limb, this movement is preceded by *postural precedence effects*, i.e. muscular adjustments to preserve the balance of the body.

According to Reed (1988:52), the insufficiencies of traditional motor control theories are pre-eminently exposed when required to explain

> ... the phenomenon of so-called postural 'compensation' for movement. The attempt to treat human movements as displacements caused by mechanisms of reflex, or centrally programmed, responses leads to a whole series of puzzles concerning how the nervous system balances and coordinates the body during active movement.

Reed (1988:72-73) subsequently points out that any of the several action cycles that comprise a common everyday task like eating would require postural adjustment prior to movement; examples are

> [e]xtending the head forward [which] tends to open the jaw ...; lifting the arms [which] may cause body sway ...; head rotation and arm movements [which] are interrelated ...; and breathing and balancing [which] are coordinately interphased.

Employing the motor systems approach to describe these skills would simply become a practical impossibility:

> In addition to having to postulate an immensely complex network of motor programmes, reflexes, and sensorimotor feedback circuits, all somehow adapted to each other by cognitive and motivational mechanisms, one also has to postulate an interconnected series of postural adjustments which are also adaptively coordinated (Reed 1988:73)

which leads Reed to conclude that "[t]raditional motor control research and theory, developed to explain the displacements of single limbs in space, is simply irrelevant to the movements and postures of actors in the environment".

Reed (1988:54) states that classical motor control theory has held that postural precedence adjustments are based on feedback about disturbances in balance. In particular, it has been believed that disruptions in balance, whether caused either by unexpected events in the environment or voluntary movements, are corrected automatically through mechanisms activated by sensory feedback.

Reed (1988:54), however, contends that there are two main reasons, supported by experimental evidence, why precedence effects can not be regarded as "reflexive, or as low-level closed loop sensorimotor mechanisms". The first is that

> ... postural precedence effects do not occur in specific muscles, or even in specific anatomical linkages, but in functionally specific regions. ... [T]he postural activities are organized in body

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> regions (which may be anatomically quite diverse) that provide support ...

According to the second reason it is maintained that

> ... in a reaction time paradigm, where subjects can respond or not respond to a signal, one can show evidence of postural preparation prior to *non-movements* ... on those trials where no response is called for.

At the present time, it is generally believed among motor theorists that postural precedence effects are controlled by a combination of feedback and preprogramming[18] - according to Reed (1988:55), it is important to note "... the tacit assumption [that] if a movement is not reflexive, or sensorimotor feedback based, then it must be centrally driven or programmed".[19] Unfortunately, Reed (1988:58) does not get so far as to actually present the "... novel and useful reinterpretation of these phenomena" that is possible in terms of action systems theory.

While the questions around postural precedence effects appear to be of considerable theoretical significance for exposing the limitations of motor systems theory, it is not clear how explaining postural precedence in a functional manner will benefit learning of piano-technical skills. A question can nevertheless be identified with respect to postural precedence and piano playing, which will be stated here briefly. It simply concerns whether the postural adjustments required for maintaining a seated posture at the piano - which could vary among individuals from hunching over the keyboard to leaning backward so that the arms tend to approximate straight lines - have any influence on motor activities of the fingers, hands and arms involved in playing. If Taylor's notions on posture discussed in Section 4.2.2.3 are correct, it would intuitively be suspected that precedence effects indeed do influence coordination at the keyboard. Unfortunately, however, this matter will remain obscured in uncertainty until addressed through a proper scientific research effort.

4.2.4 Action systems and action cycles

Any coherent act is constituted of various contributing *action systems*[20], which on their part are comprised of characteristic *action cycles*. Reed (1988:65,67) considers all action cycles in humans to be "... rooted ... in the diurnal cycle and, to a lesser degree, in the seasonal cycles".

In traditional motor systems theory the notion that movement patterns are run off by motor

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[18]Neurophysiological experiments are cited by Reed (1988:55) which have lead traditional motor control theorists to come to the aforementioned conclusion. An account of these experiments is not included here in view of the behavioural level of analysis of the present study.

[19]This dichotomy was referred to earlier in Section 4.1.

[20]The human action systems and basic actions - the particulars which are not of immediate interest for the present study - are listed by Reed (1988:66).

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programs implicitly attempts an explanation of *how* these actions occur. The claim that actions are constructed from postures and movements, however, is in itself not explanatory of how actions takes place. While the mystery thus remains on how movements and postures are functionally organized (Reed 1988:64), "[e]ven if we knew all the processes underlying postures and movements, which we do not, and even if we knew all the rules for the perceptual guidance of action - which we also do not [know]", action systems theory is presumed to be correct in stating that a human being is at any time involved in a variety of functional activities which overlap on a continuous basis. This can be inferred from the fact that

> [t]he basic orienting system, the appetitive and investigatory systems are operating continuously in the waking state and, very likely, also operate (in a much reduced fashion) during sleep. Locomotion, manipulation, speech, and play break up the day in varying clusters of activity as ... does eating. In humans, expressive activity only desists during sleep - and then not completely. Our faces are continually modulating their expressions as we engage in one activity or another. (Reed 1988:67)

According to Reed (1988:67), therefore,

> ... the problem of explaining the organization of action becomes one of explaining how these various streams of activity are *nested* into unified acts. And, where agents are capable of accomplishing more than one thing at one time, how the streams are kept *separately* nested, cycling in parallel.

Unfortunately, research into these problems at present is not even in the initial stages of gaining momentum;

> ... as yet we know very little about the action cycles of even a single action system, and there have been no studies whatsoever devoted to the rules by which people nest several action cycles into functional basic acts. (Reed 1988:73)

Reed (1988:68) proposes that the first step in a study of action should be to discover the range of variation of an action in order to determine which systems are nested into a functional coherent act. Once this range of variation is known, it can be controlled for experimental purposes. In pouring, for example, one would take under consideration the manner in which test subjects hold on to the cup, or the sequence in which subjects adjust the relevant objects before pouring begins - keeping in mind always that "... what ... subjects do vary are not responses, but functionally meaningful units of the pouring action: postures and movements, ecologically considered".

4.2.5 Basic actions

Reed (1988:68) defines *basic actions* as

> ... the most important nesting of postures and movements under a particular set of evolved environmental constraints, and as such they constitute the repertory of human daily skills. ... [B]asic acts are *not* 'innate' in the sense of genetically inherited patterns of movement; nor are they simply learned due to environmental constraints. They are *ecological* facts about the human *species*, not genetic or behavioural facts about individuals.

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While owing its origins to the species, basic actions may however be further developed in the individual (Reed 1988:47). A representative example of an ecological fact particular to humans is the fact that people of all cultures eat with their hands; given the human anatomy and the human's ecological situation, the probability that the hands will be used for eating is so great, that it is not necessary to have this characteristic trait determined genetically (Reed 1988:69). Thus, in an infant,

> ... there need be no genetic programme for a 'bringing to the mouth' movement nor need there be some kind of reinforcement of reaching responses for hand-feeding to develop. What is needed are functional perceptual and action systems in the baby, and enough interest and motivation to begin to act.

At this stage, the definition of a basic act may be refined as follows (Reed 1988:69):

> What makes a basic act a definite entity is not a stereotype of configuration, but a *definite range of variation* which has been established by natural selection and within which most individuals of a species stay most of the time.

A simple example is that of human walking: people usually walk by using both feet; it is however possible to move along by hopping on one leg, for instance for the purpose of engaging in play.

Reed (1988:69-70) does not feel that consideration of rather obvious basic acts such as standing or walking are trivial or superfluous:

> We have concentrated so much on ascertaining the facts about the alleged mechanisms underlying certain simplified movements under conditions that are quite subtle and unrepresentative of daily life that we do *not* know, in anything like a scientific way, what the skills of everyday living are.

Subsequently, Reed (1988:70) comes to the rather startling conclusion that

> [w]e certainly do not know how to characterize the movements and postures involved in many of the most fundamental human bodily skills, nor are we well informed about what constitutes the normal range of variation of those movements and postures.

4.2.6 Tool use with specific reference to the hand

Action systems theory holds that (Reed 1988:75) "... tool use evolved out of ways of enhancing the basic acts of our human action systems". Humans use tools to extend their capacity for perception and action: "[o]ne can feel as well as *poke* with a stick. Note that one does not feel the stick, but through the mediation of the stick one feels some other object" (Reed 1988:74). The principle of interest here, which has not been explained yet, is that "... awareness of the tool becomes secondary to the awareness of what we are acting upon with the tool ...". In a different sense, this statement holds for piano playing as well: in performance, the accomplished pianist will be more aware of the sound picture than the keys that are depressed on the keyboard, which can here be regarded as the "tool".

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According to Reed (1988:75), traditional motor control theories cannot be used to explain tool use. The irony is, however, that tool use skills are fundamental to the bulk of experiments from which these theories are inferred or by which they are substantiated. Typical tool use in such experiments would for instance involve the control of levers and joysticks, and the pushing of buttons in response to signals. Schmidt's (1988b:62) explanation of the functioning of the *pursuit rotor* used in tracking experiments is cited here to illustrate how complicated tool use in the laboratory can get:

> [A pursuit rotor has]... a target (usually a small circle) that is embedded in the surface of a turntable-like structure, and it rotates at a speed of 40 to 80 RPM. The subject holds a stylus in the preferred hand and attempts to keep its tip in contact with the target as it rotates.

A study of tool use should have some considerable advantages for piano playing. This is due to the fact that a tool, except for being an object serving as extension to the body, can also be considered "... an object inserted into an action cycle" (Reed 1988:75). The hand has from earliest times served as a tool for *inter alia* digging, grasping and kneading. Reed (1988:76) points out the fact that in neither of these cases the actions are defined by movement patterns: "... all of [these actions] can in fact be realized by a multiplicity of movement patterns. For example, one can grasp a tube as easily horizontally as vertically ...".

Some of the strongest indications in the literature on piano technique of an approach in which the hand is considered as a tool are found in the instructions and advice given on octave playing.

Neuhaus (1973:124) declares that correct use of the hand as an octave-playing tool causes

> ... a certain strong "hoop" or "semi-circle" from the tip of the little finger across the palm to the tip of the thumb, the wrist being maintained *absolutely essentially* [sic] in a dome-shaped position lower than the palm. This is far from easy for small hands and not at all difficult for large hands.

He stresses that for small-handed students the wrist should be held lower than the palm, all support being concentrated in the semi-circle and not in a raised wrist (Neuhaus 1973:125). It is furthermore possible to use this tool in four ways: octaves can be executed with the main distribution of activity in the fingers only, with the wrist only, from the elbow with the forearm only, and in passages requiring considerable volume "... with the whole arm, which from fingertip to shoulder joint forms a strong, resilient but unbending pivot ... excluding all movement of finger, wrist and elbow joint ..." (Neuhaus 1973:126). Slenczynska (1974:38) reports on making the hand

> ... into a stiff "octave mold" ...; the middle fingers [are] curled under so that they will be out of the way.

Whiteside (1961:53) adds some effective imagery in stating that for octave playing at high speed and volume, although the entire body is involved, it is the movement at the wrist that stands out as the "... crack of the whip"; similar imagery is used by Fleisher (Montparker 1986:11).

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Suggestions of a "tool-like" application of the playing apparatus to issues of piano technique other than octave playing are also fairly common. Fleisher (Montparker 1986:11) states that the pianist's movements can be divided into two classes according to the nature and composition of the human body: "the upper arms for details, and ... the main corpus, the trunk, which takes care of the loose and supple movement, but should remain basically still". Neuhaus (1973:94) notes that in producing great volumes of sound, the fingers relinquish their roles as independently active units to become "... pillars, or rather arches under the dome of the hand" being able to bear the weight of the body. Evenness in playing can be obtained by

> ... ensuring that the arm, quiet, loose and practically motionless, is supported by the fingers acting as props: with such playing the knuckles are naturally raised ... . The arc formed by the finger from its point of support on the key to its beginning on the hand, supports, just like in architecture, the ... natural free weight of the arm. (Neuhaus 1973:118)

Whiteside (1969:39-40) states that the wrist should be considered a joint for transmitting action rather than for producing positive action, in that it allows the up-and-down action of the forearm to "flip" the hand into the required position with respect to the keys.

This section is concluded with Reed's (1988:73) statement that "[i]t is ... a real indictment of psychology that the analysis of tool use is still in a most rudimentary stage". It can only be hoped that this state of affairs will change for the better, as piano technique could benefit considerably from scientific knowledge of its particular use of the hand as a tool.

4.2.7 The dynamical systems approach[21]

The dynamical systems approach to motor behaviour entails that human limb movements are considered to be analogous to systems of levers and masses, swinging around joints under the influence of forces like gravity. Active muscle, in particular, can be modeled as a spring with non-linear characteristics which

> ... shows systematically increased tension as the length (stretch) is increased, but with some falling-off of tension with extreme lengths. To a first approximation, the muscle acts like a 'complicated spring', in that the tension developed at a given level of activation is a function of its length... (Schmidt 1988a:9)

Thus many movement characteristics, for instance "... maximum velocity, the position at which maximum velocity is reached, the time to peak acceleration ..." (Schmidt 1988a:10) can be explained in terms of a dynamical system model, or interlinked systems consisting of masses and springs.

The event of the dynamical systems approach has given rise to the question (Schmidt 1988b:262)

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[21]*Dynamics* is "a branch of mechanics [in physics and applied mathematics] that deals with forces and their relation to the motion of bodies" (The Penguin English dictionary 1985:258).

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of

> ... why it is necessary to invent elaborate central codes and representations to account for the regularity we see in human movements, when so much of this regularity can be had "for free" by considering the dynamic properties of the moving limb-muscle system.

Motor systems theorists, for instance Schmidt (1988b:264), values the dynamical systems approach as a way to simplify motor programming theories of movement, as was pointed out in Section 2.8.6:

> [b]y considering the well-known property of muscle to behave like a "complicated spring" and by designing a motor program to *exploit* this feature of the motor apparatus, a complex trajectory can be achieved with a minimum of complexity in the program itself.

The fact that action theorists view the matter rather more radically, is acknowledged by Schmidt (1988a:9):

> The goal [pursued by action theorists] has been to account for *all* of the order and regularity found in skilled limb control (and speech) via such [dynamical] processes, rather than to postulate that any of the order and regularity was embodied in the CNS in the form of central prescriptions (or motor programmes) for the actions. [Italics added]

The problem of infinite regress has been referred to previously as one of the main action viewpoint criticisms against the motor programming notion. Schmidt (1988a:16), however, points out that the same problem is present in some of the action dynamical models of limb trajectories. It is not known how the coefficients for the terms in the differential equation[22] describing the movement is set up or pre-determined, or, in general,

> ... how *this* particular organization is set up, how it is realized physiologically, and how the system 'knows' that this is the organization which will accomplish this task ... And, because this organization will have to be changed to accomplish some other task ... from where does this *alternative* organization arise?

Another concern raised by Schmidt (1988a:16) is the fact that

> ... such modelling efforts involve a search for mathematical *descriptions* which will account for the observed data. As such, it is unlikely that the model chosen (a) will be the *only* model capable of accounting for the data or, as a result, (b) will tell us in any strong way about the underlying mechanisms.

Schmidt (1988a:17) finally points out that some of the differential equation models that can be employed to describe the experimental data are essentially "... the kinds of ideas specified by the motor programming viewpoints".

It is once again not clear how the advantages of a dynamical approach to movement would be applied to the complex activities involved in piano playing, as dynamical systems paradigms apparently have not yet been designed to address small-muscle movements as finely refined as those associated with piano technique. One would nevertheless presume intuitively that certain oscillatory

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[22]Because of its mathematically involved nature, this topic is not dealt with here more fully. Some explanatory notes are however given by Schmidt (1988a:15).

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movements, concerned mainly with larger parts of the playing apparatus, which appear to be "self-sustaining" once the right "feeling" has been established, for instance the execution of octave tremolos (as referred to in Section 3.2.1.2), are ideal candidates for description by means of a dynamical systems differential equation. From a theoretical point of view, in any event, it is important to be aware of the existence of this approach, especially in view of its arguments on the invalidity of the notion of central control.

4.2.8 The action approach to information assimilation

In the action systems approach, as opposed to the motor approach, an important area of focus is the way in which the organism interacts with information from the environment;

> ... the older views ... either did not involve environmental information at all, or ... viewed its reception by the organism as passive, with information processing activities then later used to decode it (or make sense of it). (Schmidt 1988a:11)

In contrast to the traditional viewpoint, "[e]cological views regard information pickup as *direct* ... not requiring elaborate information processing to detect its implications for action".

Control of the process of nesting movements into postures requires perceptual information. Orientation of body members with respect to another is, according to Reed (1988:63) "... a purely propriospecific function. The hand can be related to the trunk, and the trunk can be related to the head, regardless of how any of them are oriented to the ground". However, for these inter-orientational relationships of body members to be functional, "... a coordinate ability to orient one's whole self to the direction of gravity, the path of locomotion, obstacles on the ground ..." is required; this ability is based on what is termed *expropriospecific* information, or information specifying one's position with respect to the environment. Human beings' main source of expropriospecific information is vision.

In order to conduct the present discussions on information pickup from the environment in an organized manner, it is first of all necessary to clarify the relevant terminology, which *inter alia* includes terms like sensation and perception. This will be followed by a discussion on Gibson's notion of the senses as perceptual systems.

4.2.8.1 Sensation, perception and proprioception

Gibson (1966:1) points out that the verb *to sense* has two distinct meanings; "... first, to *detect something*, and second, *to have a sensation*". The related term *to perceive* also has two meanings, namely "to understand, realize" and "to become aware of through the senses" (The Penguin English

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dictionary 1985:604).

Some remarks are in order here for further clarification of these terms. When the senses are used to perceive in the sense (*sic*) of the second meaning of the word, the first meaning of the term *to sense* is valid, i.e. the relevant connotation is that involving *detection* by the senses. The second function of the senses, namely endowing humans with sensations, is by no means the same as those facilities of the senses that enable them to perceive. Thus Gibson (1966:2) regards it necessary to

> ... distinguish the input to the nervous system that evoke conscious sensation from the input that evokes perception ... The detecting of stimulus information without any awareness of what sense organ has been excited, or of the quality of the receptor, can be described as "sensationless perception". But this does not mean that perception can occur without stimulation of receptors; it only means that organs of perception are sometimes stimulated in such a way that they are not specified in consciousness.

Thus it can be said, in an apparently paradoxical manner, that perception is not based on sensation, where sensation refers to having sensations. But perception is always based on sensation as the detection of information. The distinction between sensing in *sense perception* and sensing in *having sensations* is further elucidated by Gibson (1966:58) as follows:

> The former is sensitivity to information while the latter is sensitivity to something else - energy, or the receptors excited by energy, or the nervous pathways transmitting the excitation by energy, but in any event a kind of sensitivity to be considered separately.

It seems appropriate here, while clarifying terminology pertaining to human information gathering from the environment, to explain in greater detail what is meant by the concept of a *stimulus*. In the sense it is normally used in psychology, the term stimulus signifies "... an object of some sort that is *presented* to or *applied to* an individual, rat or human, in a psychological experiment", any stimulus usually being applied as light (colour), sound, or odour (Gibson 1966:28). Gibson, however, emphatically points out that a distinction should be made between the *source* of a stimulus and the stimulus itself; "[t]he former are objects, events, surfaces, places, substances, pictures, and other animals. The latter are *patterns and transformations of energy at receptors*." It is also necessary to distinguish between an available stimulus and an effective one, the latter quality being dependent on *inter alia* the presence of an observer and the state of his receptors.[23]

It has been pointed out earlier in the present study[24] that the difference between perception and proprioception lies in the fact that the former has to do with the environment, while the latter applies to the body. According to Gibson (1966:44), it is furthermore necessary to discriminate between imposed stimuli, which is forced on a passive organism, and obtained stimulation, which is caused

[23]In the literature on piano playing, the idea of an internal stimulus is acknowledged as well; Kochevitsky (1967:31), for example, identifies as an auditory stimulus "the inwardly heard tone".

[24]In Section 1.3.

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by activity - implying that it is necessary to consider the following four categories for the reception of stimuli:

- imposed perception
- imposed proprioception
- obtained perception
- obtained proprioception

Imposed perception, or exteroception in the classical sense of the word, is the kind of perception generally studied by psychologists and physiologists. It "... arises from the skin, nose, mouth, ears, or eyes when these organs are passive and the stimulation impinges on them, or is applied to them" (Gibson 1966:44). *Imposed proprioception* occurs when the limbs of the passive individual are moved without any participating effort on the part of the individual (Gibson 1966:44-45). *Obtained perception* is described by Gibson (1966:45) as "... [arising] from the classical sense organs when they are oriented to the environment by way of the body and when they are active, that is, when they adjust and explore so as to obtain information." Finally, *obtained proprioception* occurs when the individual executes performance tasks requiring voluntary control. Proprioceptive systems overlap with the perceptual systems, but do not correspond with them; thus smelling and tasting are not regarded as proprioceptive, or muscle sensitivity as perceptive (Gibson 1966:45).

4.2.8.2 Perceptual systems

In Chapter 2 considerable interest has been focused on the theoretical approach involving human beings as processors of information. Models were proposed for the way information is picked up by the senses from the environment and subsequently processed through various stages to lead in the final instance to some sort of motor response.

Gibson (1966) does not regard the different senses as mere passive receptors of stimuli or producers of visual, auditory, kinesthetic or other sensations, but rather thinks of them as interrelated perceptual systems, or, as Carmichael puts it, "... active seeking mechanisms for looking, listening, touching, and the like" (Gibson 1966:v); he also holds that "... the perception of reality is not something assembled or computed by the brain from an ever-varying kaleidoscope of sensations". The senses therefore, when considered as perceptual systems, can obtain information about the environment without the intervention of an intellectual process (Gibson 1966:2). Gibson (1966:5) sums up the essence of his understanding of the capabilities of humans and animals *to sense* as follows:

> ... the input of the sensory nerves is not the basis of perception as we have been taught for centuries, but only the basis for passive sense impressions. These are not the data of perception, not the raw material out of which perception is fashioned by the brain. The active

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> senses cannot simply be the initiators of *signals* in nerve fibres or *messages* to the brain; instead they are analogous to tentacles and feelers. And the function of the brain when looped with its perceptual organs is not to decode signals, nor to interpret messages, nor to accept images. These old analogies no longer apply. The function of the brain is not even to *organize* the sensory input or to *process* the data ...

Carmichael (Gibson 1966:v) notes that the vast amount of sensory experiences, identified and studied in laboratory experiments in the fields of psychology and physiology, involving passive stimulation of rigorously controlled receptor organs, are treated by Gibson as "... by-products of perception rather than building blocks". It is pointed out by Gibson (1966:6) that efforts aimed at a better understanding of the perceptual facilities should not be directed at the neurophysiological level of analysis:

> Since the senses are being considered as perceptual systems, the question is not how the receptors work, or how the nerve cells work, or where the impulses go, but how the system work as a whole. We are interested in the useful senses, the organs by which an organism can take account of its environment and cope with objective facts.

Gibson (1966:47 ff.) identifies and describes five perceptual systems which are not mutually exclusive, but often focus on the same information; the same information can be assimilated by a number of perceptual systems acting together, as well as by one perceptual system working on its own (Gibson 1966:4). The perceptual systems are classified by modes of activity and not by modes of conscious quality experienced by an individual, as would be the case with the classification of sensations (Gibson 1966:49). They also correspond to the organism's organs of active attention; in everyday life these perceptual systems, also known as external modes of attention, are simply referred to as looking, listening, sniffing, tasting, and touching. They are, however, not to be confused with the human passive abilities "... to *hear*, to feel *touches*, to experience *smells* and *tastes*, and to *see*, respectively" (Gibson 1966:51). Each perceptual system orients itself in an appropriate manner for the pickup of information from the environment, while being supported by the basic orientating system for the whole body. Expressed in more formal terms, the five perceptual systems are

- the basic orienting system
- the auditory system
- the haptic system
- the taste-smell system
- the visual system

Gibson's (1966:50) description in tabular form of the five perceptual systems is reproduced in Figure 4.1. The table includes information on the following: modes of attention, impinging stimuli, and external information obtained via the particular perceptual system[25].

[25]Information on the receptive organs and their anatomies are not of immediate importance for the present study.

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Name	Mode of Attention	Receptive Units	Anatomy of the Organ	Activity of the Organ	Stimuli Available	External Information Obtained
The Basic Orienting System	General orientation	Mechano-receptors	Vestibular organs	Body equilibrium	Forces of gravity and acceleration	Direction of gravity, being pushed
The Auditory System	Listening	Mechano-receptors	Cochlear organs with middle ear and auricle	Orienting to sounds	Vibration in the air	Nature and location of vibratory events
The Haptic System	Touching	Mechano-receptors and possibly Thermo-receptors	Skin (including attachments and openings) Joints (including ligaments) Muscles (including tendons)	Exploration of many kinds	Deformations of tissues Configuration of joints Stretching of muscle fibers	Contact with the earth Mechanical encounters Object shapes Material states Solidity or viscosity
The Taste-Smell System	Smelling	Chemo-receptors	Nasal cavity (nose)	Sniffing	Composition of the medium	Nature of volatile sources
	Tasting	Chemo- and mechano-receptors	Oral cavity (mouth)	Savoring	Composition of ingested objects	Nutritive and biochemical values
The Visual System	Looking	Photo-receptors	Ocular mechanism (eyes, with intrinsic and extrinsic eye muscles, as related to the vestibular organs, the head and the whole body)	Accommodation, Pupillary adjustment, Fixation, convergence Exploration	The variables of structure in ambient light	Everything that can be specified by the variables of optical structure (information about objects, animals, motions, events, and places)

Figure 4.1 The perceptual systems (from Gibson 1966:50).

It is interesting to note that the perceptual systems can be influenced by learning; according to Gibson (1966:51),

> [i]t would be expected that an individual, after practice, could orient more exactly, listen more

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carefully, touch more acutely, smell and taste more precisely, and look more perceptively than he could before practice.

In the sections below, the auditory, haptic and visual systems will be examined in somewhat more detail[26]. The aim is mainly to form a more complete understanding of the approach to perception on which action theorists have based their work, as opposed to the information-processing perspectives described in Chapter 2.

(a) The auditory system

According to Gibson (1966:75), the function of the auditory system is not merely to permit the individual the experience of auditory sensations, but rather to enable him to *listen*. The exteroceptive and proprioceptive functions of the auditory systems are described as follows by Gibson:

> Its exteroceptive function is to pick up the *direction* of an event, permitting orientation to it, and the *nature* of an event, permitting identification of it. Its proprioceptive function is to register the sounds made by the individual, especially in vocalizing.

The *listening system* consists of two ears plus the muscles for directing them to the source of sound.

(b) The haptic system

Gibson (1966:97) describes the haptic system as

> [t]he sensibility of the individual to the world adjacent to his body by the use of his body ... [I]t is an apparatus by which the individual gets information about both the environment and his body. He feels an object relative to the body and the body relative to an object.

The haptic system is equipped with receptors that are distributed all over the body; "... this diversity of anatomy makes it hard to understand the unity of function that nevertheless exists" (Gibson 1966:134). Its principal use is to obtain information about the environment; by getting hold of an object, a person can detect many of its qualities. In such instances, all these qualities are picked up by "... exploratory manipulation, that is, by the hands considered as a perceptual subsystem" (Gibson 1966:129).

Whether the use of the hands as perceptual systems is of particular importance for piano playing, is an open question. The sensations experienced by the various limbs, muscles and joints are probably of greater importance, and thus do not fall in this category, because the perceptual systems are concerned merely with information pickup, not with the qualities of sensation.

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[26]The basic orientating system has already been discussed implicitly in earlier sections dealing with posture, for instance Section 4.2.2.1, while the taste-smell system is not of relevance for the present study.

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(c) The visual system[27]

The visual system is the perceptual system relied upon most by humans for receiving information about their environment.

In his efforts to point out how environmental stimuli impinge on the visual system, Gibson (1966:187-188) identifies eight subsidiary components to what he terms the *principles of ecological optics*, including *inter alia* radiation from a luminous source, reflection of light from surfaces, the network of projections in a medium, the ambient light[28] at a single convergence point, and the ambient light at a moving convergence point.

Schmidt (1988b:79) singles out as of particular interest the phenomenon of ambient light at a moving convergence point, i.e. the movement of the visual field when either the environment or the observer moves with respect to the other:

> As the individual and/or the environment moves, the angles of these rays [that strike the eye when reflected from every visible point in the environment] change to allow the subject to extract a pattern of movement from the changing visual array.

According to Schmidt (1988b:80), Gibson's above interpretation of how the visual system extracts information from the environment is of considerable importance for many types of sports and games, where patterns are relatively easily recognizable due to the large-muscle movements these games consist of. The same can apparently not be said of piano playing, which is mostly a matter of small muscle responses - especially in view of the renouncement by some piano pedagogues of the use of visual feedback in performance (see Section 3.2.1.3). The discussion on observational learning (see Section 5.2.2.2) seems to confirm this notion; therefore any further examination of Gibson's rather elaborate exposition on the visual system is refrained from here.

4.2.9 Piano playing as a goal-directed activity in the action systems theory sense

4.2.9.1 Technique and the aesthetic goal

Radocy and Boyle (1979:287) describe a *goal* as

> ... something toward which an organism directs its behavior ... All *purposeful* behavior is

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[27]The evolution of the visual system, which is not of particular importance for the present study, is described by Gibson (1966).

[28]*Ambient light* is light reflected by the environment as a source (Gibson 1966:186).

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directed toward a goal, which is not necessarily obvious, spiritually uplifting, or "important".

According to Starke, as quoted by Schmidt (1988a:13), the concept of a goal in the action context should be understood as follows:

> In the ecological (or action) approaches, the goal is an understanding of the mutual relationship between the environmental information and the motor behaviour that an animal displays; the focus is at the level of the animal-environment interface. It is almost like the old 'black box' approach to understanding behaviour ... in which input-output relations are the primary focus, and mechanisms occurring inside the 'box' are almost never addressed.

Apparently, the psycho-technical school of piano technique saw piano playing as a pre-eminently goal-directed activity in the sense described by Starke; according to Kochevitsky (1969:17), this school suggested that

> ... the more our consciousness is diverted from the movement, and the stronger it is concentrated on the *purpose* of this movement, the more vividly do artistic idea and tonal conception persist in the mind. Consequently, the artistic conception creates a desire for its realization, the will-impulse occasioned thereby becomes more energetic, the needed natural movement is found more easily ...

Many individual authors seem to have similar notions about piano playing; Fleisher (Noyle 1987:88) regards piano technique as

> ... the ability to do what you want to do. Therefore, you must want to do something, not just to go to the instrument and to put down levers in a certain succession at a certain speed. You must want a musical idea. You must have a certain intention, and the ability to do that is the index of your technique.

Whiteside (1961:3) defines the problem of piano playing as "... how to transfer what is a bodiless aural image into the ultimate contact of fingers against a keyboard of black and white keys", while Bolton (1980:11) and Lee (1977:6) define technique as respectively "... the ability to play (*a*) the right sounds, (*b*) of the right duration, (*c*) exactly at the required moment and (*d*) with a definitely chosen quantity and quality of tone", and "... a physiological and mental control of the bodily movements required in the production of an artistic performance".

It is indeed a well known and often-stated fact in the literature on piano playing that musical and technical development should go hand in hand. According to Schnabel and Wolff (Wolff 1972:22), "[i]n moments of great intensity, the spiritual and physical aspects of making music can become so completely unified that it is no longer possible to tell where one stops and the other begins". Neuhaus (1973:82) notes that the integration of the aesthetical side with the technical side should be a minimum requirement for the process of learning to play the piano; it is in fact ideally desired that musical insight should start to be developed *before* the development of technical skills. According to Prostakoff and Rosoff (Whiteside 1969:20), Whiteside even believed that the human body is so constituted that the physical coordination used when emotional involvement is present in a

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performance is different from the physical coordination used when emotional involvement is absent, a view which is shared by Fleisher (Noyle 1987:92-93):

> ... when you ... impose a musical intention upon the passage that you've worked out purely physically, there comes to the physical a different kind of emphasis, a different kind of stress, a different kind of tension ...

According to Prostakoff and Rosoff, Whiteside was the first to uncover that there is in fact a physical basis not only for virtuosity, but also for continuity and aesthetic beauty in performance (Whiteside 1969:9). Thus Fielden (1961:3) notes that the ingenuity and inspiration of so-called great players "... conveyed itself to their physical movements as well as to their aesthetic expression: indeed their aesthetic expression was the result of their physical movements".[29]

On the other hand, a case can also be made out for the reversal of the order of things; Fielden (1961:161) states that a good interpretation is impossible without a sufficiently developed technique - "technical lapses are apt to cause discomfort sufficiently to detract from the fulness of spiritual inspiration which the interpreter may wish to convey". He warns against the "very dangerous" tendency to put technique second to interpretation; a tendency which often manifests itself in arguments contending that a good interpretative effort with inadequate technique is preferable to a technically brilliant performance lacking in aesthetic substance. According to Fielden, the former predisposition could "... reduce any art to mere dilettantism".

While the aesthetical side of piano performance supposedly is to be a major help in approaching and conquering the pianist's technical problems, it is worthwhile to note that a lack of technical proficiency can inhibit the pianist's inherent musical qualities, and thus his aesthetic intention, from being deployed to the full, even in the case of the extremely gifted. An example that stands out is that of Ashkenazy (Noyle 1987:7), who comments as follows on his early years of piano study: "[m]y love for the music I heard around me was tremendous, but because I had to overcome physical obstacles on the piano, I suppose I stupidly wasn't expressing very much". Schnabel and Wolff (1972:22) refer to the "gap" that can arise between the mental conception of a piece and its physical realization: "[t]he audience wrongly receives the impression that the performer does not like or does not understand the piece, whereas he is simply unable to bring his conceptions convincingly to the fore". In view of the above, the viewpoint of Gieseking and Leimer (1972:47), that it is harmful to pay attention to the interpretation of a piece while it is being studied, because the student is too preoccupied with the technical problems, does not come entirely expected.

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[29]It is interesting to note in this context the similar views of two eminent pedagogues on the subject of fingering. According to Neuhaus (1973:141), in fingering physical convenience comes secondary to an accurate rendering of musical meaning, for example phrasing; it can be observed from the examples provided by Neuhaus (1973) that this does not necessarily imply that a "musical" fingering is inconvenient. In a similar vein, Bolton (1980:10) points out that the "right" fingering is the "... easiest fingering that will give us the right phrasing".

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To take the above arguments even further, a particularly astute comment by Schultz (1936:vi) on the technique-versus-musicality issue is reproduced here: according to him, a subtly concealed fear is prevalent under pianists

> ... that a persistent use of the reasoning mind in reference to the objective phenomena of technique results finally in the deterioration and atrophy of the subjective emotions upon which the interpreter's art depends.

Schultz is of the opinion that this fear

> ... explains the defiant and insistent sentiments with which theorists are wont to commingle their technical precepts - sentiments all handsomely to the effect that *music*, after all, is the thing. It explains the ever present *bête noir* of all our pedagogy - *over*emphasis on the technical phases of playing. It explains the sharp resentment of technique which is unaccompanied by interpretative insight, as if the technique were the *cause* of the emotional insensibility.

Another counter-argument to the notion that technique will "come naturally" when interpretation or musical expression is made the focus of attention, is expressed by Ashkenazy (Noyle 1987:6) as follows:

> ... the more I play, the more I think about everything, the more I come to the conclusion that the more you want to express, the more difficult it is to do everything. The mechanical problems are such that you can really almost overcome everything. But when you want to do something, then everything becomes difficult ...

This, however, does not prevent him from relying on a *Gestalt* approach to music making (Noyle 1987:8); "... I always have the overall view in my mind whenever I do anything".

4.2.9.2 Whiteside's approach to piano playing

The present section will investigate the rather original approach to piano playing of Abby Whiteside, which appears to be relevant in an action theory context for reasons that are explained below.

Whiteside's philosophy of technique was essentially aimed at bringing about a so-called "natural" coordination in her students[30]. Bridges regards Whiteside as a *Gestaltist* in the sense that she wanted the body as a whole to transfer the idea of music into the actual production of music (Whiteside 1961, 1969):

> ... although she did not go on to say this explicitly, most of the imagery she used to describe coordination - her unique concept of rhythm, her concentration techniques - all pointed to this body Gestalt. (Bridges 1985:57)

According to Whiteside (1969:41), the combinations of actions in playing the piano cannot be

[30]According to Prostakoff and Rosoff (Whiteside 1969:3), Whiteside in fact tried to convey to her students the effortless kind of physical activity used in improvisation - commonly found in jazz pianists - to the playing of the "classical" piano literature.

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isolated; it can however prove useful to be aware of certain combinations of actions in order to prevent bad habits from forming. The emphasis on using the playing apparatus as an integrated system, rather than concentrating on the workings of individual limbs, is well illustrated by Whiteside's (1961:69) explanation of how large horizontal distances should be traversed at the keyboard: in particular, easy control of horizontal distance lies in the use of the upper arm, which is the only section of the arm "... which can produce a coordinated action and right balance in activity with all the other levers". Being able, due to the turning of its bone in the circular shoulder joint, to function in any plane, slight movements of the upper arm make possible large actions by the forearm. Also, the hand should not be trained to act independently from the arm, as the hand functions as part of the whole as well (Whiteside 1961:48).

It is of some interest to note here that some authors extend the physical *Gestalt* idea to provide for the instrument as well in the plan of things. Kessler (1981:31) thus states that "[j]ust as the violin lies inside the violinist's arm or the cello stands between the knees of the cellist, the piano and the pianist should become one entity". Fleisher (Montparker 1986:11), however, points out the rather obvious fact that pianists can not be compared to orchestral instrumentalists; "[p]ianists can put down a note and go out and have a cup of coffee - that's how connected the effort is to the sound".

Implicit to Whiteside's approach was her concept as a *Gestalt* of the music as well; in this regard Prostakoff and Rosoff (Whiteside 1969:4) note that Whiteside's approach to technique differs from all other teachings, in the sense that other approaches deal with the production of individual tones when addressing the physical motions involved in playing; there is nothing which deals with the production of a phrase.

A recurring theme in Whiteside's writings is that of an all-encompassing rhythm, which is the underlying coordinating factor in piano technique. Unfortunately, in spite of the various references to this rhythm scattered throughout her two most important monographs (Whiteside 1961,1969), the precise meaning of the concept, as well as its application to piano playing, remains somewhat enveloped in vagueness[31]. Gerig (1974:474), citing Whiteside (1969:10-11), manages to synthesize the following rather coherent description of the concept of an all-encompassing rhythm:

> In Abby Whiteside's teaching an all-encompassing, long-line rhythm moves down through the music for the pianist outlining the phrases and pointing up the form. It gives a feeling of flow and continuity of movement and tends to interrelate each note to every other one. Without it, a sense of timing in performance ... [is] impossible. She observes that this fundamental rhythm is especially noticeable in an orchestral performance. The first-chair men can be spotted immediately "by their swaying bodies as well as by listening to their lilting phrases". ... But left on his own the pianist does not have the benefit of the singer's breathing, the

[31]Bridges (1985:57), rather appropriately, notes on this rhythm that, "[b]eing a non-verbal experience, it was difficult for Whiteside to describe".

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> violinist's bow arm, or even the skater's balanced activity to force him into a long-line phrase procedure and a compelling rhythm in his body. He must use full arm and bodily participation in order to achieve such a rhythm.

According to Whiteside (1961:14,38), the upper arm can be regarded as the prime coordinator of the basic, phrasewise rhythm. But Gerig (1974:475) also points out the rather curious notion that "[t]he torso itself frequently must bounce and dance to the music".

Another important aspect of Whiteside's technical approach, which also appears to have certain action theory premises as basis, is that she defines the motor tasks required for piano playing *functionally* through the use of imagery. The reasons why imagery delivers better results than an explicit account of the action of levers in terms of the nature of muscles to act in areas is explained by Whiteside (1961:60) as follows:

> Muscles act in areas, and when imagery stimulates a coordination there is no boundary line for these areas. There is, instead, cooperation from all the areas. When good imagery suggests a result there are far more chances for nature to take over the coordination in a skilled manner than when a so-called factual analysis of leverage is made.

Whiteside (1961:60) continues to clarify the goal-, or image-orientatedness of her approach to piano technique as follows: "[a]ll we need is a desire, an imaged result, and we move and act expertly to get the thing we desire. What we do in action as a means to the result, we are totally unaware of most of the time". Unfortunately, in applying her ideas to their fullest consequences, Whiteside sometimes comes to rather contentious conclusions, for example (Whiteside 1961:50): "... the importance of a prescribed fingering is practically nil ... If a rhythm is working, a finger will be ready to deliver power".

4.3 The action systems approach to motor learning

Reed (1988:79) distinguishes between the nature of motor skill learning under the motor systems approach and its nature under the action systems approach as follows: when traditional theories of motor learning are concerned, skilled actions can be described as displacements of bodily limbs in space, and

> ... learning a skill as an adult, or developing skills as a child requires the acquisition of specific neuromuscular units of movement, along with the motivational and cognitive abilities to control and constrain these movements.

When, on the other hand, skilled movements (actions) are considered to be constituted by

> ... ecologically orientated postures and the movements that change them in the service of particular functions, then skill learning involves the acquisition and coordination of a number of basic acts for each of the several human action systems.

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The latter concept of learning involves what has been described by learning theorists as *practice without repetition*; learning of a skill then "... is not the acquisition of a pattern of movements, but a functional organization of whatever postures and movements serve to get the job done" (Reed 1988:79).

According to Reed (1988:80), exceptions do exist where learning the skill involves learning to make a specific movement pattern; he cites dance, sports like gymnastics and even some music skills, as cases where it is required that certain movements should appear "correct" to a judging observer. This fact, however, does not nullify the functionality argument, as it is debatable whether human observers judge movements by quantitatively analyzing spatial displacements of limbs.

Finally, Van Wieringen's (1988:113) notion should be pointed out that the action approach is not suited to the explanation of motor learning, because cognitive structures are avoided.

4.4 Limitations of the action systems approach as seen from the motor systems perspective

While Schmidt (1988a:14-15) welcomes the shift in focus proposed by action theorists towards the role of the environment as determinant for motor control, he is however

> ... compelled to ask, "So, how then do we actually *move*?"

in view of action systems theory's lack of analyzing the events inside the "black box"[32] in the sense that information-processing, for example, is explained under traditional motor systems theory (see Chapter 2). Van Wieringen (1988:89) is of the opinion that motor systems theories are a *sine qua non* "... if it is wished to explain more than a very restricted subset of relevant data".

Perceiving an apparent difference in levels of analysis, Schmidt (1988a:13) declares that the action view's focus on the goal in motor behaviour forms an excellent basis to point out the differences between the action and motor approaches

> ... in terms of *what* is the target of explanation. In the action view, the explanation is in terms of what the motor view would term 'input-output' relations, while in the motor view it is usually in terms of mechanisms of motor control. More fundamentally, the difference seems to be in terms of the *levels of analysis* at which the theorizing occurs.

Thus, Schmidt (1988a:14) prefers to state that it is probably not valid to weigh the motor perspective against the action perspective, because these theories attempt to explain different things,

[32]This analogy will be discussed in Section 4.2.9.

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although admitting that the two approaches are not operating at totally different levels of analysis. Schmidt, as a motor theorist, is conspicuously far from declaring action systems theory as outrightly wrong, contrary to certain action theorists' stance on the motor program.

4.5 Summary and conclusions

Action theorists dismiss the motor systems approach to motor control and learning as an incorrect application of the computer metaphor to humans. A major argument in support of this statement is that the peripheralist-centralist dichotomy adhered to by motor theorists is not valid for the reasons pointed out by Reed. The nature of the internal representations and cognitive structures assumed by motor theorists to account for motor control and information-processing in itself requires explanation, thus giving rise to more questions instead of solving the present ones. Motor theorists regard all movement as built up out of neuro-behavioural units; action theorists, however, feel that these basic units should rather be defined ecologically.

A common goal for action and motor theorists is to identify how the degrees of freedom available to the organism is constrained, so that the control of a number of degrees of freedom to form a motor response is handled as a single unit. Motor theorists advocate the motor programming idea, but action theorists adhere to the idea of a coordinative structure, i.e. a group of joints and muscles acting together as a unit.

Actions were shown to differ from the motor systems theory concept of movement in that they are functionally defined in terms of the organism's interaction with the environment, while movements are merely defined as displacements in space and time. The constituent subsidiary components of actions are functionally defined actions themselves. Postures and movements, in themselves actions, were identified as the constituent components of any action, postures being the orientation components, with movements the functionally nested changes in posture. While the ultimate posture in humans is to maintain an upright posture, the goal of this action being to keep the perceptual systems orientated to the environment, the method presented by Taylor suggests that posture can also serve the purpose of equipping the pianist with the ultimate in coordinative powers, i.e. technique. In particular, by cultivating what Taylor terms the expanding posture, the performer will be able to play anything he can sight-read almost at the first attempt. While Taylor's approach seems to be extremely attractive due to its doing away with piano practice in the traditional sense, achieving the expanding posture seems to be a highly sophisticated affair, at least in the initial stages; guidance by a qualified teacher seems to be imperative. The fact that Taylor's approach is apparently built on a single principle only, i.e. the virtues of the expanding posture, intuitively gives rise to some concern;

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as Schnabel and Wolff (Wolff 1972:23) point out, "... gymnastic considerations have lead some teachers to building their training on just *one* facet of body activity ...". Taylor furthermore supplies no findings obtained through scientific experiment to support his thesis; more research is necessary to determine in an empirical manner whether the expanding posture indeed increases coordinative facilities for piano playing, and whether a positive finding in this regard will have any implications for the action notion of skilled motor behaviour.

The inadequacies of traditional motor systems theories are exposed to the fullest when required to explain postural precedence effects. The influence of postural precedence effects on piano playing requires some further investigation; experiments based on motor systems premises, however, would seem to be unsuited for this purpose.

It was pointed out that humans at any stage are involved in a variety of functional activities which overlap continuously; thus various action systems are running at the same time, each of which consists of various action cycles, which in turn are comprised of the postures and movements that are functionally selected to comply with that specific task goal. To illustrate the foregoing, it can be postulated with respect to piano playing, that one action cycle governs the right hand and another the left hand. These cycles are nested within another action cycle that controls the hands playing together. A different action system is concerned with maintaining the seated posture at the piano, while another action cycle regulates pedalling. At the same time, a multitude of action cycles are involved in the coordination of less obvious movements and functions. The problem of explaining human motor behaviour thus becomes one of explaining how various streams of activity are nested into unified acts, and how some of these streams are kept to cycle separate from each other. At the present time, however, initial research into this matter has not even gained momentum yet, and this fundamental question thus remains unresolved.

It is not clear which basic actions are underlying to the movements of piano playing. Reed's statement that it is not even known yet how the postures and movements involved in the basic skills of everyday life should be characterized does not auger well for a scientific understanding of highly refined motor skills such as piano playing.

An investigation of the literature on piano methodology reveals that the hand is often regarded as a tool for piano playing. Traditional motor control theories cannot be used to explain tool use. This makes the realization that tool use was required of test subjects, in many (if not most) of the experiments substantiating various motor systems theories of motor control and learning, all the more disquieting. Any research efforts to elevate the understanding of human tool use beyond its present highly rudimentary state, could hold some advantages for piano playing as well.

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The dynamical systems explanation of human movement is seen by certain action theorists as a complete negation of the need for elaborate centrally-driven motor programs to control movement. Motor programming theorists however point out that, as in the case of motor programs, unanswered questions remain on how the differential equation setup which organizes the relevant movement patterns originates. Certain movement patterns in piano playing would intuitively seem to be well suited to description along dynamical systems lines, and as such should be worthy of some further research.

The ecological view regards pickup of information from the environment as direct, not requiring the elaborate information-processing associated with the motor systems view. According to Gibson, the different senses should not be regarded as mere passive producers of sensations, but rather as interrelated perceptual systems, or active mechanisms for looking, listening, touching, and so on, which orientate themselves appropriately for pickup of information from the environment. An individual can learn to use his perceptual systems more effectively, which accounts for the comments made on the use of intrinsic feedback in the previous chapter. The implications of dealing with perceptual systems, rather than passive receptors, for piano playing can only be speculated upon in view of the lack of experimentally-verified findings.

Various references to piano playing as a goal-directed activity in the literature, the goal being a certain aesthetically-justifiable musical concept, seem to confirm the notion that piano playing can indeed benefit from a functional approach to its problems. It is suggested that concentrating on the goal will cause motor execution to follow in a "natural" manner, i.e. in a manner ecologically appropriate for the task, or that motor execution will at least be greatly facilitated because of an inclination towards being functional in nature. Other authors, however, contend that no aesthetic expression is possible if a sufficiently strong technical basis does not exist beforehand, rendering this matter somewhat uncertain.

It was found that various aspects of in particular the approach of Abby Whiteside suggest an implicit action approach to piano playing. Whiteside states that the combinations of actions in piano playing cannot be studied in isolation, in effect acknowledging the idea that many action systems and cycles are running at the same time, constantly overlapping and nested within each other. She sees the playing apparatus as an integrated system rather than in terms of the workings of individual limbs; in this regard one would be inclined to refer to the piano playing system in a sense similar to Reed's action systems and Gibson's perceptual systems. Movements are functionally defined; therefore it is apparently not necessary to use a prescribed fingering, i.e. the planning of finger movements in terms of space and time. In particular, imagery is used to functionally describe movements in piano playing; movements are not described kinematically or dynamically, i.e. in the traditional motor

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systems theory sense. The state in which the pianist functions in harmony with his playing environment, i.e. when all playing occurs "naturally", is synonymous with Whiteside's idea of an all-encompassing basic rhythm.

Whiteside appears to have many staunch followers who have benefited from her methods. It is however not quite clear from her monographs precisely how this basic rhythm can be established in pianists unfamiliar with her approach, i.e. how learning of technique takes place. The general attractiveness of her methods, which can in part be attributed to the fact that no distinction is made between practice and performance, clearly warrants some further, scientifically-based empirical investigations. Until then, it is not possible to assess their validity.

The action approach to motor learning appears to be rather vaguely defined at the present time; some authors even regard action systems theory incapable to explain learning because of its avoidance of cognitive structures. The action idea of practice without repetition, which involves the functional organization of postures and movements to get the job done, appears to be particularly attractive. More research is clearly necessary to initiate clarification of this matter.

It was pointed out that action systems theory has exposed many of the shortcomings of the motor systems approach; some motor theorists however hold that the action approach does not offer any viable alternatives to their explanation of how humans move. Also, action theorists seem to avoid in their discussions the topic of highly skilled motor behaviour such as that found in piano playing; instead, the emphasis appears to be on the phylogenetic skills.

The action systems approach, nevertheless, is acknowledged by both Adams (1987) and Schmidt (1988a) to be a main line of research for the future, and it is believed by Reed (1988:81) to have the potential for representing a radical new start in man's study of human action:

> ... Gibson's ecological psychology, with its theory of action as based on what the environment affords the animal, and on the pickup of information specific to these affordances, by an agent's active perceptual systems, provides an entirely new and promising beginning for studying action in a way that will be relevant to practical concerns.

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CHAPTER 5

CONCEPTS FROM MOTOR CONTROL AND LEARNING AS A BASIS FOR PRACTISING THE PIANO

5.1 Introduction

In previous chapters an attempt has been made to explain, in broad terms, both advantages and fallacies of the motor systems and action systems approaches to motor control and learning. The purpose of the present chapter is to determine whether it is indeed possible to extract from the maze of rather abstract concepts presented earlier, some useful information with regard to the structuring of activities and time spent at practising[1] the piano. According to Gieseking and Leimer (1972:46), perhaps *the* most important duty of the piano teacher is to teach the student how to practice; a teacher "... deserves the greatest praise if he untiringly points out to the pupil the best way to work". According to Owen (1988:84), efficiency in practice can be enhanced by a systematic method of instruction in practice techniques. Additional efficiency in musical instrument practice can be gained from instruction with respect to the role of schema in motor learning at the piano (see Section 3.4.2.7). It should be reiterated here that this chapter, like all the other chapters, is *not* concerned with the incalculable number of physical strategies that can be employed from the piano teacher or pianist's point of view for better scale playing, faster trill execution, and so on. Rather, the emphasis will fall on an effective way or ways to get such a movement pattern, once it has been decided on, "automaticised" as quickly and effectively as possible.

It has been stressed before in the present study, that extremely little empirically-based information on piano playing appears to be available. Thus, a worthwhile approach to the problem of applying motor behaviour science concepts to piano playing, would be not so much an attempt to present

[1]Radocy and Boyle (1979:312) allows for a rather wide definition of the term *practice*: "Depending on one's theoretical position, one may regard practice as exercising or strengthening stimulus-response connections, applying a learned response to a new stimulus, anticipatory goal-seeking responses, or searching for insight".

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indisputable truths, but rather to investigate if it is not possible to find discrepancies in views generally accepted by pianists and teachers because of tradition or habit. It is indeed a fact that to illustrate that "something is *not* as has been supposed" is also a contribution to any field of study.

In correspondence with the approach suggested by Schmidt (1988b:377), those variable parameters which can be directly controlled by the teacher or learner, will be concentrated on. Such an approach, of course, is in line with the generally behavioural level of analysis of the present study.

Finally, some attention should be given to the research area aimed at investigating how piano students structure their practising sessions by their own initiative. The purpose of such an approach is, of course, to obtain directions for practice with some amount of general applicability. In this regard, Gruson (1988:93) states that, although practice is without doubt the most critical aspect of the skill acquisition process, the behaviour of music students as they practise, is an area still left mostly uninvestigated. This problem was therefore addressed by Gruson (1988) in a study which investigated general[2] musical acquisition, by examining the behaviour in rehearsal of piano students varying in musical competence from the first grade to concert pianists. Gruson (1988:106) subsequently found that significant changes in practising behaviour takes place as students become more skilled as musicians -

> [e]rrors, repeated notes, and pauses tended to decrease with competence while self-guiding speech, total verbalizations, playing hands separately, time spent on each piece, and, particularly, repeating sections ... increased as music level increased. (Gruson 1988:101)

Across practice sessions, however, fewer behavioural changes occurred. At all levels of proficiency, tempo increased across practice sessions, the required tempo being attained earlier by the more advanced pianists. The most significant finding, according to Gruson (1988:106-107), was "... the change in the units of music repeated during practising as musical experience increased". In particular, as skill increased, students repeated sections of music more often, tending to use less notes at every repetition.

Gruson (1988:110) identifies an area for future research that could be of particular interest for students and teachers of piano alike:

> If it is indeed possible to isolate more mature or effective practising strategies, it would be interesting to investigate by means of a specific training programme whether practising is modifiable or whether it is purely a function of experience.

In the following sections various possible contributing factors to more effective practising strategies will be identified, while an attempt will be made to explain their influence on practice in

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[2]I.e., motor aspects, although omnipresent, were not specifically isolated for study.

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terms of the principles of motor control and learning discussed earlier.

5.2 Prepractice conditions

The effectiveness of practice is influenced by some factors which are operant even before actual practising begins. The two factors regarded by Schmidt (1988b:378-379) as of the most significance will subsequently be discussed here; they are

- motivation
- developing a concept of the task

5.2.1 Motivational aspects[3]

Most learners and teachers know intuitively that motivation is important for engaging in effective practice, especially in view of the fact that the practising experience can be far removed from an emotionally satisfying one. As John Browning (Noyle 1987:26) acknowledges: "... every artist gets angry in practicing. ... So there are times that you hit the keyboard, and there are times you swear four-letter language. It's hard work. It's like dishwashing. It isn't fun." Two important determinants of motivation are briefly mentioned here. The first is the importance of making the task that is to be learned seem important (Schmidt 1988b:378). While the general interest in so-called "classical" music according to some observers appears to be declining, the question could be asked why it is worthwhile to spent hours a day practising the piano while the world around one essentially thrives on "instantaneous" happenings; it is possible, for instance, to establish communication to almost any place in the world within seconds. The second aspect has to do with the setting of goals[4]. Locke and Bryan (1966:286) found that the setting of performance goals in a psychomotor task resulted in intensified effort at all stages of activity. Schmidt (1988b:379) singles out for attention, that part of their experiment which involved one group being told to "do your best", while the other group was encouraged to strive for a higher level of achievement. It was found that the second group actually performed better than the first - although it is not certain whether this effect should be attributed to the learning process, or the temporal influence of motivation (Schmidt 1988b:379). What is certain, is the fact that the goal should not be set too high either, as this could result in the detrimental effects, associated with too much arousal, which were explained in Section 2.6.

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[3]Although the present study is not primarily concerned with the affective aspects of learning, it is nevertheless necessary to take heed of the motivation factor in motor learning, as neglecting it could jeopardize even a carefully planned strategy for practice.

[4]The word is not used here in the sense it was used in the discussions on action systems theory in Chapter 4.

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5.2.2 Developing a concept of the task

Schmidt (1988b:379 ff.) identifies five techniques for assisting the learner in "getting an idea" of the task to be mastered, namely

- verbalized instruction
- modelling of the task
- verbal pretraining
- knowledge of principles from physics and physiology
- establishing a prepractice reference of correctness

These subjects will now be subjected to closer scrutiny.

5.2.2.1 Verbalized instruction

While the limitations of verbalized instruction has already been pointed out in the introduction to the present study, it is nevertheless worthwhile to make some additional comments on this subject. Schmidt (1988b:379-380) is of the opinion that verbalized instruction can fulfil three tasks, namely to give the student an overall concept of the movement as guide to the first attempt, to help the student to recognize his own errors by "checking" on the spatial state of limbs during or after movements, and to make the student aware of what *not* to do. He then points out, however, that instructions are often overused in, and not entirely sufficient for, situations where learning is required:

> Words alone are relatively crude descriptions of the complex kinds of movements that a learner is attempting to achieve ... Only the most global, general aspects of the intended movement are going to be transmitted through verbal instructions. Also, a learner can remember only so many instructions ... (Schmidt 1988b:380)

Verbalized instruction of course abounds in the literature on piano playing. Townsend's description of what true "finger independence" should look and feel like - as quoted by Gerig (1974:364-365) - is perhaps an example of the nature and format of the information that the learner should receive before the practice session:

> True independence, cultivated to its highest point, gives the hand and arm a constant appearance of naturalness and grace, convincing the onlooker of a feeling of comfort in the player .... The training of the hand therefore, must, from the beginning of study be based upon the idea that movement in any finger which causes simultaneous movement in any other finger is not independent enough. Every finger-movement - to be a really independent one - must be made without occasioning the movement of any other part of the hand. The strictest inhibition of all other movements becomes then as important a matter as is the movement itself. But this inhibition is impossible as long as the weight of the hand and arm is incorrectly used, or, in other words, as long as the hand and arm are not balanced.

In the "balanced" state, the arm should display the following characteristics:

> The balanced state is that in which, when the fingers are resting on anything - in the present case the keyboard - the whole limb from shoulder to finger-tips is at any moment ready and

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> willing to swing: up, down, sideways, or circularly, at the wrist; or sideways at the elbows; and the problem to be solved by the student is, how to practise and at the same time preserve this condition of balance as a constant bodily habit. (Gerig 1974:365)

Finally, the apparently common practice among teachers, to define the different ways sound can be produced on the keyboard by employing verbal metaphors, should be noted. Neuhaus (1973:100) for example, in order to describe "freedom" in piano playing, compares the arm with a hanging bridge, the shoulder and fingertips being the bridge posts. However, as soon as the hand and fingers are raised above the keyboard, "... the image of the bridge is no longer accurate and it is better to think of a crane ...". The views on imagery of another staunch advocate, Abby Whiteside, were already pointed out in Section 4.2.9.2.

Unfortunately, it is not possible to give at this stage any empirically-verified indications of how a strategy for effective verbalized instruction should be organized, because "[e]xperimentation in motor learning has been negligent in this respect" (Schmidt 1988b:380).

5.2.2.2 Modelling of the task and observational learning

Modelling is often used along with instructions to aid the learning of motor skills. One technique of modelling employs "... movies, loopfilms, videotapes, or even photos of skilled performers" (Schmidt 1988b:380). Examples of the latter are found quite frequently in the literature on piano technique, for example the series of photos showing Annie Fisher playing the first three or so measures of Chopin's *Fantasie Impromptu* in Gát (1958:48-49), and the photos of the hand engaged in various activities in Schick (1982:17-20). But the most important type of learning based on skill demonstration is probably *observational learning*, to which this section will be devoted in its entirety.

The common approach to observational learning is to watch someone else perform. Almost all of the methods for piano technique, presented from the beginning of the eighteenth century through most of the nineteenth century, had as a basis the visual analysis of the motions involved in piano playing (Bridges 1985:19). The popularity of a visual analysis approach to the movements of the arms, hands and fingers in piano playing is easy to understand - sight is the only sense, apart from hearing, through which it is possible to directly perceive the playing of another person. It is furthermore far easier to describe movements that are visible, than to verbalize kinesthetic sensations as they are experienced by a specific person (Bridges 1985:19).

In spite of the fact that even everyday experience has proved that observational learning sometimes works, the field has been subject to some neglect due to, among other historical reasons, the fact that (Adams 1987:62) "... dominant fathers of the psychology of learning in the United States ... never

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had much luck with observational learning, and so learning operations that worked moved centre stage". Developmental psychologists have however always maintained an interest in observational learning "... because of their belief that children learn much of their language and social skills in that way" (Adams 1987:63).

Following Bandura (1977:22 ff.), Adams (1987:63) notes that the function of observational learning is to impart "... a cognitive representation (not a template) to the observer. The cognitive representation could be verbal, as with a verbal description of the model's behavior, or nonverbal, like an image." This cognitive representation can be used in two ways, namely

(1) to serve as a guideline for the actions of the observer when the observed behaviour must be reproduced

(2) to function as a standard of correctness for the detection of error between the response and the representation.

Adams (1987:63) identifies as a major reason for the field of observational learning being "incomplete", the fact that

> ... there are important dimensions of the movement that are unavailable to the subject's view. ... The cognitive representation is incomplete without these dimensions, and so the reproduced movement will be imperfect.

Examples of such unavailable dimensions are pressures executed by for instance the fingers in piano playing, muscular tensions, and external features of the movement that cannot be seen. Ortmann (1981:8-12) uses a vector diagram to represent the various forces that may be involved in producing a movement; even if the resultant, or observable, movement may appear simple, the "... composition of forces shows why the visual aspect of movement is not a safe guide to the muscular causes of the movement, since this may result from a few or many components" (Ortmann 1981:12). Gerig (1974:417) points out some more cases of "visual illusion", for instance the fact that no movement does not imply that no muscles are active - "... opposite sets of antagonistic muscles may be contracting against each other with equal force, rendering movement impossible", while Neuhaus (1973:103) observes that extensive practising of motor skills in piano technique - like scales - leads to movements "... hardly perceptible to the naked the eye". It is therefore not surprising that Lee (1977:3) regards the method of learning technical skills through visual and aural demonstration in private lessons and master classes, transferred in music teaching from generation to generation, as

> ... a rather ineffective and uninnovative approach, especially in an era in which educational philosophy constantly evokes new trends as educators search for more effective and efficient methods to match the advancement in science and culture.

However, "... ingenuous ways might be devised to make the unobservable observable" (Adams 1987:63), as was demonstrated by Carrol and Bandura (1982), who made use of a television system to make observable that parts of a complex arm movement that are normally obscured; the usefulness

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of a close-up filming of the fine muscle movements of a skilled pianist remains an option to be investigated.

Observational learning is not only concerned with watching accomplished performances. In passively watching a model *learn*, an observer will see the model's behaviour change over trials, and "... something undoubtably will be learned" (Adams 1987:63).

But when the observer in addition gets insight into the model's knowledge of results, he "... not only forms a cognitive representation but can join the model in other cognitive activities as well". (Experimental findings have indeed shown that the benefits obtained by a test group of observers, who watched a model learn with information on the model's knowledge of results, were "more stable and enduring" than those associated with a test group which only observed the model learning). The observer can use his developing cognitive representation of what is required in a skilled performance in order to identify errors in the response of the model. This perception of error can subsequently be checked against the knowledge of results that the model receives. The next step for the observer will be " ... to use this error information to project the correction required on the next trial and then, on the next trial, see whether the model did it".

The idea of observational learning by watching another performer learn with insight into his KR and KP - combined with the additional dimension of listening - certainly is not new to the field of piano playing. In this regard Fleisher (Montparker 1986:7-8) recalls picking up valuable information from attending the lessons of co-students of Artur Schnabel; he even holds the notion that the observer, because he is not under pressure to perform at that moment, is likely to be more than usually perceptive in such situations of learning.

Finally, it should be stated that how much actually can be learned through observation - with or without making observable the components of a movement that are normally obscured - is still unknown, and thus the hypothesis that "... a cognitive representation acquired by observation is inherently impoverished and incapable of wholly governing a refined, expert skill" has neither been fully proved, nor disproved, empirically (Adams 1987:63-64).

5.2.2.3 Verbal pretraining

Schmidt (1988b:422) defines *verbal pretraining* - which is somewhat of a misnomer since this type of preparatory training is not necessarily verbal - as "[t]he presentation of stimulus or display elements of the task in isolation so that they can be more easily responded to in later whole-task performance". On such presentations of stimuli, the learner would be expected not to merely watch

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passively, but to respond in a mode different to what the manner of response would have been in the actual execution of the task (Schmidt 1988b:382). An example would be a racing car driver exploring the race course by foot, verbally responding to questions on the outlay of the course.

A similar approach could benefit the pianist, for whom the keyboard is analogous to the race course in the previous example: Kochevitsky (1967:42), for example, points out the rather subtle fact that, due to the arrangement of black and white keys on the keyboard, harmonically identical intervals "... sometimes requires not only different positions of the fingers (depending on black and white keys), but also different stretches for similar intervals and similar combinations of white and black keys". Kochevitsky illustrates this point by presenting the different widths of three cases of minor thirds with the ground note on a white key and the other note on a black key, i.e., f - $a^{\flat}$ = 35 mm., c - $e^{\flat}$ = 38 mm., g - $b^{\flat}$ = 39 mm. Thus it could be worthwhile for especially small-handed pianists to keep in mind, when attempting high-speed arpeggio playing, that slight differences do exist between apparently similar arpeggios, like F Minor and C Minor.

5.2.2.4 Knowledge of principles from physics and physiology

The idea that knowledge of the physiology of the playing apparatus of the pianist can help to enhance planning a strategy of practice is certainly not new; the extensive research done by Ortmann (1981) and the emphasis placed on physiology in their technical treatises by *inter alia* Gát (1958), Ching (1946) and Fielden (1961) testifies to this. Fielden (1961:8) in fact regards as shortcomings in the methods of Breithaupt and Matthay - the latter after which "... the English pianistic world would never be quite the same" (Gerig 1974:398) - the fact that

> ... neither of these men ... sufficiently emphasized the necessity for scientific knowledge of physiology, and the relations and co-ordinations of muscular actions; nor did they insist enough on a knowledge of the laws of mechanics, as far as the application of the laws of leverage was concerned.

Gerig (1974:413) notes that the criticism was raised, "particularly among emotionally dominated pianists", that the scientific approach of Ortmann to piano playing would adversely affect its aesthetic component, the sciences being of a "cold"[5], unemotional nature; Schultz (1936:vi) mentions the existence of a

> ... half-conscious and almost universal suspicion that there is a fundamental incompatibility between a mind interested in the mechanical phases of playing and a mind filled with what is loosely known as musical temperament

[5]Ahrens and Atkinson (1955:36) whole-heartedly endorse a scientific approach to piano playing. Yet this laudable fact does not save them from making the rather enigmatic statement that "... we should always be able to accept *hard, cold facts*" (italics added). Facts, as can be attested by any person familiar with them, are hardly ever experienced as "hard" or "cold".

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Gerig (1974:413) points out that one of the true reasons for this aversion with respect to the scientific approach was rather that "[i]t was quite likely ... that pet theories might be destroyed".

According to Neuhaus (1973:87), an attempt to a more general and accurate terminology should not be regarded as intervening with or undermining the "spiritual", or aesthetic, facet of music -

> ... let this [not] worry those who hold the "mystery" of art so dear: the mystery of art remains unfathomed, retaining all its force and scope, just as in life. But one should not see the "unfathomable" where common sense, against which we all of us sin so much, can perfectly well understand all there is to understand.

An approach to technique that illustrates how seemingly abstract principles and concepts of mechanics can be used to explain matters of piano playing, is that of Neuhaus (1958:86-87): in his lessons, Neuhaus used from physics the symbols *F* (representing force), *m* (mass), *h* (height) and *v* (velocity) - relating them to the playing apparatus of the pianist - as an aid to his students for "... understanding and using the physical possibilities of the piano, considered as a mechanism"[6]. In fact, he regarded the cultivation of the ability to view piano-technical problems from such an angle, as an integral necessity to the pianist's make-up (Neuhaus 1973:87):

> ... the better a pianist knows the three components ... first the music, secondly himself and thirdly the piano ... the greater the guarantee that he will be a master of his art ... . And the greater his ability to formulate his knowledge with precision in statements even remotely akin to mathematics and that have the force of law, the more profound, sound and fruitful will his knowledge be.[7]

In spite of the arguments in favour of knowledge of principles from physics or physiology underlying piano playing, it nevertheless appears as if some pianists fare quite well without such knowledge, becoming highly accomplished at their instrument. Due to lack of empirical information in general on the influence of knowledge of such principles on practising, it is not possible as yet to make any definitive statements on the subject at the present time (Schmidt 1988b:383).

5.2.2.5 Establishing a reference of correctness before practice commences

Of most interest for establishing a prepractice reference of correctness for piano playing is perhaps

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[6]Neuhaus (1973:110), for example, suggested that pianists with small hands, could circumvent the problem of playing loud chords with considerable stretch, by replacing great *h* with *v*.

[7]The warning should however be exerted here that a superficial knowledge of physics will not be of much use either. Thus, for example, Taylor's (1979:43) confusing statement, apparently derived from one of Newton's laws of motion, that "[t]o every action, there is an equal and opposite reaction, therefore the resistance of the seat must at least equal that of the piano mechanism under its heaviest stress" should rather remain unsaid. Even more peculiar is the notion by Taylor (1979:55) that "... nearly all the energy expended on key-depression is returned to the performer by the rebound of the key ... [t]he total activity of a coordinated performance may therefore be expressed as a two-way flow of energy between the performer and his instrument". At the most the rebound of the key can be used as an opportunity to *save* physical effort in the sense that it is not necessary to purposefully lift the finger in order to release the key; i.e., it is sufficient to let the rebound of the key push the finger back to its original position.

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the *Suzuki* approach to violin playing, where the reference of correctness is formed by repeated listening to a model performance before practising begins (Schmidt 1988b:383)[8]:

> Presumably, as the student attempts to play, he or she compares the sounds actually made against the reference of correctness established by the recorded violin music... Deviations in the student's own reference of correctness suggest errors that must be corrected in subsequent attempts.

Kerr (1982:300), however, is of the opinion that, "... because this is a commercial technique rather than a laboratory-verified procedure, it is difficult to assess its validity".

5.3 Structuring of practice

In the following sections, eight diverse variables will be pointed out which should be kept in mind when structuring a practice session will be discussed. Most of these aspects as identified by Schmidt (1988b) pertain to the practice of motor skills in general, but some have direct bearing on piano practice. These aspects involve:

- the number of practice trials
- massed vs. distributed practice
- the time involved in massed practice
- variability in practice
- blocked vs. random practice
- the resemblance between the conditions of practice and the conditions of transfer
- slow vs. fast practice in acquiring piano-technical skills
- practising in varied rhythmical patterns

5.3.1 On the number of practice trials

There seems to be agreement among psychologists and musicians alike that the more practice trials, the more learning will occur[9]; Schmidt (1988b:384) notes that "[i]n structuring the practice session, the number of practice attempts should be maximized", while the maxim *repetitio est mater studiorum*[10] is supported by *inter alia* Gieseking and Leimer (1972:81) and Neuhaus (1973:147). The question of how the maximum number of repetitions should be fit into the time available to the learner, is addressed below.

[8]Apparently, this strategy is not adhered to in Bigler and Lloyd-Watts's (1979) application of the Suzuki method to piano teaching.

[9]Assuming that these trials are not performed half-heartedly, but with a full effort of all facilities required.

[10]Repetition is the mother of study.

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5.3.2 Massed vs. distributed practice

Massed practice can be described as (Schmidt 1988b:422) "[a] sequence of practice and rest periods in which the rest time is less than the practice time", while *distributed practice* is "[a] sequence of practice and rest periods in which the practice time is less than the rest time".

Most research on massed versus distributed tasks has been done with respect to continuous tasks. An unanimous finding was that the limited rest periods associated with massed practising, lead to a systematical decrease in performance compared to distributed practice, where more time for rest is allowed (Schmidt 1988b:384). Apparently, empirical results have shown that performance is severely affected by massing, but learning far less so (Schmidt 1988b:386), a finding which immediately gives rise to the question

> [h]ow can learners practice a task under massed conditions, when performance is clearly inferior to that experienced under distributed conditions, and yet learn just about as much? These effects seem clearly contrary to intuition, as it would seem that fatigue associated with massing would cause people to learn the "wrong" movements.

Schmidt (1988b:387) presents two hypotheses to clarify the matter: the first is that massed practising actually induces variability in the movement patterns that are practised, which leads to more effective learning, as will be explained in Section 5.3.4. The second hypothesis holds that massed practising requires more effort to master the task, thus causing more thorough processing.

Although some thought-provoking results have been obtained for the effects of massing on discrete task practising - studies have shown that massing does not necessarily impair performance during the acquisition phase, and it has even been found that massed practice increases the quality of performance, Schmidt (1988b:388) notes that it is "... probably premature to generalize very strongly from these ... studies". It appears, however, that the discrete tasks studied here would rather be relevant to skills like kicking or throwing, rendering them for the present not of critical importance to piano playing.

5.3.3 The time involved in massed practice

Apparently, no clear, empirically-based rules exist for determining how long a practice session should continue. According to Schmidt (1988b:390), experimental findings suggest that "... the most effective schedule for learning motor skills will be dependent at least in part on the energy cost of the task". Thus, a task that requires a high input of physical effort would be most effectively practised in a shorter period than a task which requires less effort; the same probably applies with respect to mental effort as well.

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It should however be emphasized that "... a single, optimal distribution of practice and rest periods does not exist, and that this choice will depend on the task to be learned" (Schmidt 1988b:390).

Views by different pianists and pedagogues seem to support the above statement; Gieseking and Leimer (1972:48), for example, holds that "[t]o practice the piano five, six, or seven hours daily is generally done without concentration and is at the same time injurious to the health". André-Michel Schub (Noyle 1987:109), however, appears to differ:

> ... I practiced as many hours as I physically could. I have to admit more than six or seven hours a day. ... I know that other people did it, too. ... With the piano, there's no way of getting around those hours at the piano if you practice to play correctly.

5.3.4 Variability in practice

In Section 3.4.2.4 schema theory has been used to explain why variability in practice of motor tasks should benefit learning. Some additional remarks with regard to variability in practice will subsequently be made.

It appears rather obvious that to practice open tasks[11] under varying conditions would be beneficial to the learning of these tasks. Yet experimental evidence has implied that closed motor skills might also benefit from being practised in different ways, with variable practice increasing the degree to which the learned skill can be applied to novel variations of the task learned. Schmidt (1988b:394) sums up the findings so far on variability in practice as follows:

> ... when adults are used as subjects, there is reasonably strong evidence ... that increased variability is beneficial for learning as measured on novel transfer tests, and basically no evidence that variable practice is detrimental to learning. But there are a number of studies which show very small effects, and others with essentially no effects, which cast some doubt on the "strength" or generality of these effects.

Thus it appears safe to say that practising piano technique could benefit from variability being introduced in some way into the learning process; with respect to which aspects of practising such variability should pertain is however not certain.

In a somewhat different vein, Owen (1988:85) suggests that practice, varied in the sense that attention is focused on different aspects of the task, should serve to develop as many schema (in the sense described in Section 3.4.2.7) as possible;

> differing images result in differing schema, and differences in performance. For example, a phrase might be thought of by its melodic direction, its dynamic contour, its relation to surrounding phrases, or by the kinesthetic feel of playing it. Each of these could produce a

[11] I.e., tasks for which the environment is constantly changing.

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different schema, resulting in differences in performance.

5.3.5 Blocked vs. random practising

Studies of *context effects* have mostly been concerned with factors that make the task to be mastered more difficult for the learner than is actually required (Schmidt 1988b:395).

An area of major interest is that of *blocked vs. random practice*, which deals with problems of the following type: three tasks, namely a certain scale, arpeggio and scale in double thirds have to learned. Which practising strategy would be the most efficient - practising ten trials of the scale followed by ten trials of the arpeggio followed by the same amount of trials of a double note scale, or changing the task on every trial? An experiment similar to this situation in organization[12] - but vastly different with regard to the type of motor tasks that had to be learned - by Shea and Morgan (1979), is cited by Schmidt (1988b:396) as representative of some noteworthy findings on the question of random vs. blocked practice. While performing the trials in random order in the acquisition phase, which resulted in an overall slower performance than was found for the group learning the trials in blocked fashion, the random group actually performed better in transfer tests, i.e. after periods of retention (in this case ten minutes and ten days respectively). Schmidt (1988b:396-7) describes this finding as

> ... curious ... especially when we realize that the Random condition in acquisition resulted in slower performances than the Blocked condition. This is another instance in which the conditions that *improve* performance in acquisition seem to degrade learning as measured by performance [after some time lapsed] ... *This certainly runs counter to the general idea that, in practice, we should always attempt to organize the conditions so that performance is maximized.* [Italics added]

One hypothesis for explaining the effects of random vs. blocked practice is that each type of practice involves a different level of processing. While subjects involved in blocked practice apparently tend to execute the movements without much thought, it is critical for the random group, for which each task changes from trial to trial, to establish a meaningful understanding of the tasks, as well as concepts of what make them different from each other (Schmidt 1988b:398). Thus the "deeper" processing by the random group apparently lead to a better learning of the task. Another hypothesis, the so-called *forgetting hypothesis,* stresses the generation of the appropriate motor program as the critical component of the learning process:

> ... random practice causes the subject to forget the "solution" to a given motor task, so that

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[12]This experiment had as the three movement tasks three variations on a task which in its basic form required that the subject had to grasp a tennis ball in a start position, knock over, in a prescribed order, a series of barriers as fast as possible, and place the ball in its finishing position. Variations consisted of changing the locations and number of barriers; subjects however received some indication of the spatial organization of barriers (Shea & Morgan 1979:180-181).

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the solution must be generated [anew] when that task is presented again. (Schmidt 1988b:398)

Of course, it is also possible to employ schema theory for an understanding of the random vs. blocked practice phenomenon, as random and blocked practice can essentially be considered two types of practice with different degrees of *variability*, the former having greater variability than the latter. Schmidt (1988b:399), however, points out that variable practice may not be such a strong premise for schema theory to claim correctness; "... variable practice in relation to schema theory could really be nothing more than context effects, and might be more effectively explained by the depth-of-processing or forgetting hypotheses ...".

If assumed that random vs. blocked practice effects, which "... seem to represent stable and dependent principles of motor learning" (Schmidt 1988b:399), are applicable to the learning of the motor skills of piano technique as well, it should be one of the major shaping factors of the practice session. As Schmidt (1988b:400) appropriately, but with some caution, declares -

> [t]he "traditional" methods of continuous drill on a particular action (i.e., practicing one skill repeatedly until it is correct) is probably not the most effective way to learn. Rather, ... practicing a number of trials in some nearly randomized order will be the most successful in achieving the goal of stable learning and retention. ... [m]uch work on these issues needs to be done, however, with different kinds of tasks and various training settings, before we can be confident about how to effectively apply these principles.

This warning should be kept in mind when structuring practice along the lines advocated by the *repetitio est mater studiorum* protagonists (see Section 5.3.1).

5.3.6 Resemblance between the conditions of practice and conditions of performance

On of the most common problems in the structuring of practice sessions is perhaps best described by the following practical example: should the difficult coda of the third movement of a concerto be practised at the end of a session of massed practice when the learner is fatigued and performance is down - which could very well be the case in the actual public performance, the movement being the final one - or should it be practised under rested conditions?

The *specifity-of-learning hypothesis* holds that practising should occur under conditions resembling as closely as possible the actual conditions under which the performance will take place (Schmidt 1988b:422). While, according to Schmidt (1988b:401), many studies tend to favour the hypothesis, its

> ... effect is often very weak, however, and does not seem to make much difference. In addition, the effects are sometimes *asymmetrical*; that is, for transfer Condition A it is far more effective to have practiced under Condition A than B; but for transfer Condition B it is only slightly more (or no more) effective to have practiced under Condition B than A.

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Some contradictory results have also been found, for instance that in transfer of learning, Condition A is more effective if the task was practised in a different Condition B rather than Condition A. An example of such a result is that random practice conditions for the acquisition phase is always more effective, regardless whether the task is performed in transfer under random or blocked conditions.

As the specifity-of-learning hypothesis clearly does not envelop the most effective approach to all situations of learning concerning the acquisition phase, attention will now be focused on the viewpoint of *transfer-appropriate processing*, which states that (Schmidt 1988b:422,401)

> ... practice should be arranged so that the *processing capability* [italics added] learned is appropriate for some goal criterion task or conditions...it is the similarity of the underlying *processes* (not simply the *conditions*) between acquisition and criterion transfer performance that will be the critical determinant of the "goodness" of practice.

Thus, allowance is made for conditions in acquisition and transfer to differ; it is more important for the designers of training to understand the *processes* underlying the actual performances, and to attempt to cultivate these processes in practice (Schmidt 1988b:402). Unfortunately, the nature of these processes that should be learned "... still must be discovered by our research" (Schmidt 1988b:402); for the purposes of structuring practice at the piano, it is only possible at this stage to take note of the fact that apparently practice and concert conditions do not necessarily have to match in order to ensure a successful performance.

5.3.7 Slow vs. fast practice for acquiring piano-technical skills

According to Neuhaus (1973:90), the old and well known principle of practising *slowly and with force* has remained in widespread use, being especially useful for acquiring the ability to produce sound of large volume as required in pieces like the Rachmaninov Third Piano Concerto. Peter Orth (Elder 1979:20), for example, recalls how his teacher, Adele Marcus, taught him to practice the Chopin *Etudes* Op. 10 No's. 5 and 12 "... very slowly, triple forte". However, the following physiological considerations should be observed when practising slowly (Neuhaus 1973:91-92):

> ... make sure that the hand and arm, from the wrist to the shoulder, are completely relaxed, that there is no contraction, no "freezing" or stiffening anywhere, that none of the potential flexibility is lost, and at the same time remain perfectly still, making only those movements which are absolutely essential ... [U]se pressure only when the simple weight of the inert mass is insufficient to produce the desired volume of tone; understand that the greater the height ... from the which the note is played ... the less pressure or effort is needed.

For Gieseking and Leimer (1972:47), one of the most important advantages of slow practice lies in that it helps the student to avoid mistakes - for instance inappropriate movements and fingering - from the outset of learning a new piece; thus Reubart's (1985:85) notion that slow practice should only be "[a]s fast as you may wish *without errors*".

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Equally well known, however, is the fact that slow practice could establish habits not suited to the coordination required for speed (Whiteside 1961:54). Schnabel (1972:173), as well, was against any form of habitual slow practising of fast passages, including "... the old device of practising even semiquavers as dotted rhythms of one kind or another" (see also Section 5.3.8).

Whiteside (1961:55) also holds that "[p]ractice perfects exactly the coordination that it uses and not something else". Of particular significance from the psychological perspective, therefore, is Handel's (1986:19) proposal that, because rhythmic organization changes at different tempos, "... the type of motor learning and type of motor program also changes at different production rates. The relationship between motor learning and music education therefore should differ across tempos." As chief motivation for this statement, he presents some findings from his study on how polyrhythms, consisting of incompatible pulse trains, are perceived when factors such as the frequency of the notes comprising each pulse train, the duration, and/or the loudness of these element notes are changed. The highly significant conclusion Handel (1986:19-20) reaches, pertains to

> ... the perceptual nature of rhythm. A slow-moving pulse train in which the inter-element interval is greater than 1 s cannot provide the sense of regularity necessary for rhythmic perception. The elements appear unconnected and disjointed. Conversely, a rapid pulse train in which the inter-element interval is less than 200 ms moves to the foreground; it becomes the *figure* (with subjectively accented elements) and cannot serve as the rhythm. ... In other words ... [w]e cannot expand or contract a music pattern in time and expect to hear the same rhythmic structure.

These results seem to be confirmed by findings obtained by Duke (1989) in experiments which required music students to tap the perceived beat or pulse in response to periodic stimulus tones. According to Duke (1989:61),

> [r]ates greater than 120 tones per minute (tpm) were apparently "too fast" to be perceived as beat notes, and pulses slower than 60 tpm seemed "too slow".

The main implication of this finding for learning of motor skills at the piano pertains to aural feedback. Suppose the learner is used to practice slowly; if his perception of rhythm changes at speeding up the tempo to resemble more closely the tempo that will be required in the actual performance, the learning process might be disrupted, because (Handel 1986:20)

> [t]he performer might be "captured" by the perceived pattern. The performer would be unable to perceive alternate organizations and be unable to create the motor programs necessary to achieve those organizations. Moreover, the performer might make timing changes to bring about the desired rhythmic organization when played at one speed, but these changes would yield different rhythmic organizations when played at a slower or faster speed. *Practising a pattern at a slower rate might be counterproductive.* [Italics added]

Another matter that arises here is that of the degree of transfer that takes place when it is required that a piece that has been subjected to some careful slow practising, has to be executed at high speed. Handel (1986:20) is of the opinion that motor patterns - and the motor programs they are controlled

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by - can be divided into different categories which correspond to different rates of execution; thus the amount of transfer "... would depend on the similarity of rates and whether the change in rate crosses a motor pattern boundary". This view of course does not agree with Schmidt's understanding of the generalized motor program[13], where the overall execution time, and thus the overall tempo, is regarded as a variable parameter of the program - the only invariant temporal aspect being the relative phasing of the movements. As another example to illustrate that the generalized motor program theory is not valid for many motor skills, Handel (1986:21) cites the common motor skill of speaking: "[h]ere, too, we do not find an across-the-board slow down or speed up of articulatory movements. Instead, at faster speaking rates vowels are sacrificed for consonants to insure intelligibility." Handel (1986:21) sums up his argument on the ability of motor programs to expand and contract motor skills in overall execution time as follows:

> ... there may be general limitations in the ability of a performer to change the performance rate: alternate perceptual organizations might emerge which conflict with the desired organization and new motor programs might be required to perform at the different rate.

5.3.8 On practising in varied rhythmical patterns

Finally, it should be pointed out that the arguments listed in the previous section for slow practice are probably just as valid for the method of practising in "rhythms", which can be considered a special form of slow practice. In view of the argument that different motor programs are required for different tempi of execution, Kochevitsky's (1967:41) viewpoint that "... using numerous and diverse rhythmic variants in scales and exercises created out of actual musical situations is a very good means for mastering ... timing", i.e. timing of successive finger movements with "the finest precision", does not ring true here. Taubman (Schneider 1983:20) has some noteworthy views on this subject which, probably unwittingly, apparently take into account the findings of Handel discussed above:

> The real issue is being able to play ... [fast] notes evenly, as written. What is the value of distortion? If there is unevenness, figure out which finger is not getting enough support from the arm. In all such problems it is important to listen and train the ear to hear the even spaces between notes. Practicing uneven notes does just the opposite.

Or as Ashkenazy (Noyle 1987:7), rather candidly, notes on the practice of mechanical exercises, "I don't have a routine prescription or something like distorting the rhythm"...[14].

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[13]This subject was explained in Section 2.8.4.

[14]Then, again, there are pianists who do ascribe to practising in rhythms, for example André-Michel Schub (Noyle 1987:112).

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5.4 Conditions of practice and transfer

The concept of transfer of learning, which has to do with the gain (or loss) in effectiveness in one skill as a result of practice on some other has already been mentioned (see Section 3.1). Many piano teachers believe that practising mechanical drill exercises, like those by Hannon, will transfer positively to the technical problems encountered in pieces from the repertoire. Another common assumption is pointed out by Schmidt (1988b:407), namely that practising component parts of a task will transfer to the whole task.

In the following sections, a motor behaviour science view based on Schmidt (1988b) to these and related matters will be presented.

5.4.1 Basic principles of transfer

According to Schmidt (1988b:407-410), three principles of transfer of motor skills that can claim some measure of generality can be identified. Until some empirical evidence is gathered, however, it remains unsure whether these principles are indeed partially or wholly applicable to the complex processes involved in the learning of piano-technical skills. Some discussion is nevertheless devoted to these general rules in view of the lack of more specific information. They are:

- "motor transfer is small"
- "transfer depends on similarity"
- negative transfer

5.4.1.1 "Motor transfer is small"

According to Schmidt (1988b:407), studies which investigate the transfer from one task to another, completely different task, typically show that "... the transfer is small or negligible". In this regard, he interprets results from experiments by *inter alia* Lindeburg (1949) to have shown that

> ... "quickening exercises" (various laboratory tasks that require rapid decision and action) provide no transfer to other tasks that require quickness. This is certainly not surprising in light of what is known about the specifity of motor abilities, as the activities in the quickening exercises probably used different motor abilities than the task to which the exercises were supposed to have contributed.

Even where similar tasks were concerned, with only a variation in the performance speed requirement, it was found that transfer was small, though higher than in the previous case (Schmidt 1988b:408). As a matter of interest, the following related remark by Lindeburg (1949:194) is added here:

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> Definitely disproved is the theory that "quickening exercises" or sports activities (such as table tennis) that involve many rapid skillful movements improve the individual's general coordination.

The possible explanation of this phenomenon in terms of motor *abilities*, or the "[s]table characteristics or traits, genetically defined and unmodifiable by practice or experience, that underlie certain skilled performances" (Schmidt 1988b:342) should be expounded upon: Schmidt (1988b:408) states that

> ... motor abilities are both numerous and specific and ... even similar tasks appear to correlate very low with each other. If so, then in transfer experiments when the task is changed in even a small way ... it is likely that different and unrelated abilities are called into play ... there might be a low transfer among even very similar tasks because the abilities are almost completely different.

These observations are of extreme importance for the structuring of practice for piano-technical skills. As was pointed out earlier, it is a widely accepted approach to practice passages that will require great speed in execution slowly at first, even after the notes have been memorized. The finding that different abilities come into play for slow and fast execution, or even execution at rates that differ only slightly, appears to support the motor programming-based notion by Handel, described in Section 5.3.7, that slow practising does not necessarily enhance fast playing.

5.4.1.2 "Transfer depends on similarity"

The notion that the amount of transfer depends on the similarity between tasks is not a new one (Schmidt 1988b:408); it is however not clearly understood

> ... what "similarity" is, and what the "elements" are that are supposedly similar in various tasks.

It has been implied that "elements" could be, among other possibilities, abilities that are common to both motor tasks, and/or the motor programs that control the execution of both tasks.

In piano playing, tasks could display some similarity in a topographical sense, for example the ability to play an Alberti bass accompaniment based on the triad C-E-G, should imply that the same figure could be played if based on the triad F-A-C (it is assumed at the C and F in question lie in close vicinity on the keyboard). While the arpeggios F Minor and C Minor appear to be topographically similar in the sense that similar configurations of white and black keys are pressed, the subtle differences between key distances as pointed out in Section 5.2.2.3 should not be ignored.

In general, however, this matter remains enveloped in uncertainty (Schmidt 1988b:409).

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5.4.1.3 Negative transfer

Negative transfer can be described as the losses that occur in one skill as the result of the experience of another (Schmidt 1988b:409)[15]. An example of negative transfer proper[16] is the difficulty experienced by learners of a second language to produce its speech sounds, a difficulty which is to a large degree related to the characteristics of sound production of the speaker's first language. Schmidt (1988b:411) notes that speakers whose mother tongue is French or German have different problems when it comes to producing speech sounds from English; one would thus refer to these difficulties as representing negative transfer from French or German to English. Of some interest for piano technique could be an experiment performed by Shapiro (Schmidt 1988b:410):

> ... subjects [were instructed to] learn complex patterns of movements with a particular experimenter-imposed timing. Later, subjects were instructed to speed up the movement, which they had no trouble doing. But when they were also told to *ignore* the temporal pattern they had learned earlier, subjects had a great deal of difficulty producing a new temporal structure. Instead, they sped up the original temporal structure, more or less as one would speed up a phonograph record.

These results are not completely surprising, though, when viewed form the generalized motor program viewpoint, according to which it would be necessary to construct an entire new program to incorporate a different temporal structure. The question arises here once again of whether practising technically difficult scale passages in varied rhythmical patterns[17] at a slower pace than required, could transfer negatively to the actual performance, where the tempo has to be accelerated and the passages performed without any rhythmic distortion, thus involving an adjustment to the temporal organization of the task. Lack of empirical investigation into this matter precludes conclusive answers.

5.4.2 Practising the whole vs. practising in parts

It is almost customary for learners of piano playing to "break up" the whole piece into parts in order to concentrate on the most problematic passages, while eliminating cumbersome repetition of the simpler parts. Thus Newport (1982:33), in a manner typically found in numerous pedagogical treatises, states that "[t]eachers should demonstrate how to practice carefully: hands together, hands alone, small sections, and only what is needed". Gieseking and Leimer (1972:26) follow suit: "[o]nly small parts should be practised at a time; and these should be repeated over and over again, so that irregularities and unevennesses may be immediately corrected". Also, intuition dictates that

[15]This topic has already been subjected to some brief scrutiny in Section 3.1.2.2.

[16]Where detrimental performance is not partly or fully caused by other factors such as cognitive confusion about what is required in the task.

[17]This topic was discussed in Section 5.3.8.

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practising a part should transfer to the whole, in view of the fact that the elements within the part stays the same, whether it is seen in isolation or in its context in the whole piece.

Schmidt (1988b:413), however, raises some reservations:

> The problem with this idea is that practice on the part in isolation may so change the motor programming of the part that it is, for all practical purposes, no longer the same as it is in the context of the total skill.

Taylor (1979:32-33) also raises an objection, namely that practising in parts divorces technique from the realities of making music. In particular, by dividing technique

> ... into different compartments [corresponding to different problems in the work], one mechanism for finger passages, another for thirds, another for octaves ... the busy pianist is constantly practising the very opposite of that simple continuous flow of gesture with which the talented performer follows the line of a work.

Taylor (1979:72) furthermore points out that, once coordination has been established through the method of Thiberge by using the expanding posture (which was outlined in Section 4.2.2.3),

> ... there is no question of chopping a work up into bits and pieces for the sake of 'practising'

provided that the pupil has formed an adequate mental conception of the work. This point of view is shared by Whiteside (1969:26), according to whom a so-called natural, or effortless, coordination is never put together after all the parts have been practised separately. However, Gieseking and Leimer (1972:48), unabashedly contradicting Taylor and Whiteside, state that

> [t]he objection that it is better to practice only complete phrases instead of dividing them up, does not hold good. ... [Division into parts] is not in the least harmful to musical feeling. On the contrary, the thorough mastering of short parts of a phrase at a time will enable the pupil to bring the complete phrase to a state of greater perfection.

In order to throw some more light on this intriguing question, it is necessary to conduct the investigation in terms of the two classes of movement tasks which have relevance to piano playing, namely serial tasks and continuous tasks.

For serial tasks, it appears as if the whole task can benefit considerably from practising the component tasks in isolation; it has even been found that spending a specific amount of time on practising components in isolation, could benefit the actual performance more than spending the same amount of time on the whole task (Schmidt 1988b:414). While the whole task can simply be reassembled from the different parts worked at in isolation, Schmidt notes that a more effective method seems to be that of *backward chaining*, "in which the last element in the sequence is systematically preceded by earlier and earlier parts until the whole chain is completed".

Schmidt (1988b:415) explains the implications of practising parts extracted from continuous tasks as follows, taking account of the fact that in certain tasks, for instance piano playing, different parts are often executed by different hands at the same time:

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> For continuous tasks, in which the behavior continues more or less uninterrupted ... the parts that can be isolated frequently occur at the same time as other parts ... Also ... the parts must frequently be *coordinated* with each other, and it might seem that breaking into this pattern of coordination to practice a part might not be very effective, as it is the coordination between these parts that must be learned.

Hence Schnabel's opposition to the practising of hands apart (Wolff 1972:173).

Schmidt (1988b:416) continues to note that, for motor tasks, like piano playing, involving the simultaneous execution of different parts, "[t]ransfer research ... is nearly non-existent ... and the decisions about part-whole transfer are merely speculative". Hence little substantiated commentary can be made on the validity of strategies like Merrick's (1958:5) "stopping practice", which, according to him, is aimed at mentally rehearsing the execution of what comes next in the music[18].

5.5 Mental practice

The idea of mental practice is not foreign to the field of piano playing. An avid supporter of mental practice as a method for advancing technical proficiency, is Jorge Bolet, who emphatically states (Noyle 1987:17) that he has

> ... never ... solved either a major mechanical problem or a musical problem at the keyboard. I practice so much at the keyboard and then I have had enough ... Whatever I do at the keyboard gives me enough practice material so that I can practice mentally, for twelve, fifteen, twenty hours, whenever I'm awake.

Bolton (1980:10) suggests that the learner, for a passage that he finds particularly difficult, should "... try thinking it without playing. Imagine the muscular sensations and the keyboard, and catch hold of the keys mentally only".

Mischa Dichter (Noyle 1987:53) also engages in mental practice, but only after the notes are learned, preferring "contact with the instrument" while the piece is still unfamiliar to him.

Ashkenazy, on the other hand, is not much in favour of the idea of mental practice (Noyle 1987:6), "... because I think you need the physical touch with a piano and your fingers have to mechanically find the right places. The mechanics also have some part, they have to be there."

Mental practice, which apparently can lead to considerable positive transfer in the performance of the actual task, can be described in rather more formal terms as "[a] practice method in which the performance on the task is imagined or visualized without overt physical practice" (Schmidt 1988b:422). Mental practice is thought to be mainly an opportunity to sort out the cognitive elements

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[18]Bigler and Lloyd-Watts (1979) apparently advocate a similar strategy, which they refer to as "STOP-PRACTICE".

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of a task, for instance the sequence of events and the reviewing of previous experiences in order to avoid mistakes that may have occurred previously; thus it should occur mainly in the acquisition phase of learning (Schmidt 1988b:417-418). Apparently, learning of the actual *motor* skills does not benefit much from mental practice. Other explanations for the benefits of mental practice are that (Schmidt 1988b:418-9) additional practice is obtained due to the fact that

> ... motor programs for the movements are actually being run off during mental practice, but the learner simply turns down the "gain" of the program so that the contractions are hardly visible

or that the performer is merely preparing himself for the coming performance by setting his arousal level to an appropriate level.

Finally, some attention should be directed towards Coffman's (1988:1086-A) experimental study to establish the effects of type of practice - physical, mental, alternating physical/mental and practice under a "motivational control" - and aural knowledge of results (KR) on improving piano performance in novice pianists[19]. The performance parameters that were investigated were performance time duration, number of pitch errors, and number of rhythm errors. Results of the investigation showed that all three groups engaged in some sort of practice, displayed faster performance time than the control group, and that the physical and alternating physical/mental groups showed faster performance times than the mental practice group, but did not significantly differ from one another. From this Coffman (1988:1086-A) concluded that "... mental practice can effectively improve the novice pianists' performance speed, especially when alternated with physical practice".

5.6 Guidance

Guidance, i.e. "[a] series of techniques in which the behavior of the learner is limited or controlled by various means to prevent errors" (Schmidt 1988b:422) is applied simply by guiding the learner through the task that is to be learned. Although guidance is sometimes regarded as a performance variable rather than a learning variable, i.e. improving the performance under which guidance is given rather than effecting the relatively permanent changes associated with learning, Schmidt (1988b:420-421) notes that it is possible to make some generalizations about guidance as a useful tool in aiding learning. The first is that guidance is most effective in the early stages of learning, when it is more important to "get the task going" rather than to produce a refined response. Secondly, guidance appears to be most effective for slow rather than fast tasks; this observation places a question mark over the extent to which guidance procedures may be of use for piano technique, because difficult technical problems are usually problems that require rapid execution.

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[19]While the present study is not aimed at piano-technical motor behaviour in children, these findings are nevertheless mentioned here for the sake of completeness.

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It is interesting to note that Ortmann (1981:96) advises against the teacher moving the learner's arm, hand or fingers through the movement patterns that are desired for efficient execution:

> The teacher supplies the force and makes the movement actively whereas the pupil makes it passively. As a result the muscles responsible for the movement do not contract ... Muscularly, the pupil has learned nothing. At most he has been given certain sensations of rotation at the joint at which movement takes place.

To render guidance effective, a force should be instead be introduced in a direction *opposite*, rather than parallel, to the direction of the required movement; "... if finger-drop be the problem, press up against the descending finger". While such an approach may seem rather unconventional, it does have a physiological foundation, namely that "... a muscular condition does not depend upon the position of the parts but upon the external resistance opposing the maintenance of the position".

5.7 Summary and conclusions

Experimentation in motor learning has been negligent with respect to the use of verbalized instruction to form a concept of the task just before practice. Apparently, verbalized instruction is generally of limited usefulness, because words are relatively crude descriptors of complex movement patterns; learners in any event can only remember a limited number of instructions. Observational learning with insight into the learner's knowledge of results seems to hold some promise for students of piano playing; the observational part is however hampered by the fact that many important dimensions of the movement are unavailable to the subject's view. The usefulness of a close-up filming of the fine muscle movements in a proficient piano performance remains to be investigated. It appears as if the use of verbal pretraining to isolate for special attention stimulus or display elements of the motor task, like the topography of the keyboard, could benefit the pianist when he is to perform the whole task later; more research is however necessary to confirm this presumption. The apparent belief among certain pianists that a rational, scientific approach to the problems of piano technique will adversely affect the aesthetic side, was shown to have been discredited by some of their colleagues. It appears as if knowledge of some principles from physics and physiology applied to piano playing could benefit the learning of piano-technical skills; again however, some more research is needed to verify this statement. The pianist should however beware of treatises misinterpreting these principles, which also have found their niche in the literature on piano technique. The validity of a Suzuki-type approach for establishing a prepractice reference of correctness in advanced piano playing, also warrants some further investigation.

The fact that performance deteriorates under massed practice conditions should not be undue cause for alarm, as the same does not necessarily apply to learning. Therefore, contrary what is commonly believed, the fatigue associated with massing does not necessarily cause people to learn ineffectively.

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The latter finding appears to be confirmed by the fact that certain pianists recommend long hours of massed practice at the keyboard. But it can also be stated that no single, optimal distribution of practice and rest periods exists; such a distribution would rather then depend on the nature of the task to be learned and certain capabilities of the learner himself, for instance his concentration ability. On the grounds of the rule-learning premise of schema theory, it seems justifiable to state that the practice of piano-technical skills would benefit from variability in the learning process. Which aspects should be varied is however not certain; a research effort aimed at clarifying this matter should be well worth the while for students of piano playing.

Brief explanations in terms of information-processing in the motor systems sense and schema theory, were offered to account for the fact that learning of motor skills in general, is more efficient under random practising conditions than under blocked practice, even though performance under the latter type of practice is better. More important, though, is the contradiction of the traditional notion - probably also held by the majority of pianists and teachers - that practice should always be structured so that performance is maximized during the practice session. Although some more research is required into the matter in general and with respect to piano playing in particular, it appears as if the traditional method of continuous repetition of a motor task until it is correct, is not the most effective way to practise; rather, a number of trials should be practised in a quasi-random order to achieve maximum learning.

Apparently, practice and concert conditions do not have to match in order to ensure a successful performance; from a motor systems viewpoint with its notion of internal states, it appears to be rather a question of cultivating in training, the underlying processes that are common to both acquisition and the concert performance situation. Unfortunately, researchers know very little at present about the nature of these processes.

While slow practice of fast passages is widely employed among pianists, research carried out on the perceptual nature of rhythm, indicated that different motor programs are required for executing the same passage at different speeds, implying that practising a fast pattern at a slower rate might be counterproductive. These findings also imply that transfer of a piece practised slowly, to a situation where execution at a high speed is required, is not as straightforward as suggested by Schmidt's use of the overall-duration parameter in the generalized motor programming situation. The significance of these findings is perhaps enhanced by the fact that some eminent piano pedagogues indeed discourage the habitual practising of fast passages at a slower rate. It was also pointed out that the former findings apply to the practising of fast passages in varied rhythmical patterns as well; as in the former case, arguments from the literature on piano playing, both for and against this method, were presented. The reasons why this form of practice apparently does not have any detrimental

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influences on the playing of certain accomplished pianists are certainly open to speculation, and thus deserves some further investigation; perhaps it does not have any influence at all, or for some hidden secondary reason, indeed enhances their technical facilities.

The view was pointed out that transfer between motor tasks is typically small, because different motor abilities come into play for different motor tasks. More research into this matter pertaining to piano technique is clearly needed. Another area worthy of research effort involves the similarity between motor tasks in piano playing, because it is known that the amount of transfer between motor tasks depends on the similarity between the tasks. Certain experiments from motor behaviour science, involving negative transfer, hint that practising in "rhythms" may transfer negatively to the undistorted and fluent execution of the relevant passage; once again, more research is needed in order to be able to make any conclusive recommendations.

It was shown that the literature on piano technique contains arguments both for and against practising parts of a piece in isolation. Motor programming theorists hold that practice of the part in isolation, may so change the motor programming of the part, that it is not the same any more as it is in the context of the whole. It appears as if serial skills can benefit more from practice of parts in isolation than continuous skills; it may thus be worthwhile to investigate the structuring of practice based on whether a particular piece displays predominantly serial or continuous skill characteristics.

Mental practice appears to be most effective when applied in interaction with some physical contact with the keyboard. Motor programming notions can be used to account for the benefits of mental practice; it appears to be possible to execute a motor program with a very low gain, resulting in muscular contractions that are hardly visible. Particularly interesting insights into the subject of guidance, however, apparently can not be inferred in this manner.

It has been shown above that explanations of a fairly wide variety of practice phenomena can be offered using concepts from the motor systems approach. The same apparently can not be said of the action approach, perhaps because research into that approach is only in its initial phases. Another explanation could be that action systems theory is not much concerned with the idea of learning through practice in the traditional sense, especially in view of the idea of practice without repetition mentioned earlier in this thesis. It would have been most interesting to watch a pianist like Abby Whiteside, whose teachings apparently display many action premises, practise; unfortunately, her monographs reveal too little in this regard. Clearly, the matter of practising under the action approach - as well as the matter of learning under this approach, as was pointed out earlier - requires some extensive research.

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CHAPTER 6

GENERAL CONCLUSIONS

The purpose of the present study has been to investigate and contrast the potential value for addressing the problems of piano technique of the motor and action systems approaches to motor control and learning, of which piano playing is one of the most sophisticated manifestations.

A fairly large variety of different aspects of the motor perspective to motor control and learning, and the action perspective to motor control, was discussed - it was found that the action approach to motor learning at present appears to be undefined to such an extent that some theorists even regard the action approach as unsuitable to account for motor learning. Examining many and varied topics from motor behaviour science - even although in some cases, for practical purposes, only essentials were pointed out - ensured that motor control and learning were to a reasonable degree represented as the highly multi-faceted fields of study they are, regardless of one's theoretical orientation. Considering a broad variety of topics also made it possible to form a conception of the "research culture" behind especially the relatively long-established motor systems approach, which was essential for an understanding of the fundamental nature of action theorists' reservations with respect to this approach. The treatment of many concepts from motor behaviour science applied to motor skills other than playing the piano, was a matter of necessity rather than choice, because scientifically-based empirical findings on piano playing in the motor control and learning context are extremely scant. In some cases, especially where conditions for practice were concerned, findings involving other motor skills were presumed to be of possible significance for piano playing as well.

If motor systems theory - and especially the notion of the motor program - is correct, then scientifically-based experimental and/or theoretical grounds exist to presume that the following premises, among others, with respect to piano playing and practising may be correct (some of the notions on practice were formulated on the grounds of experiments involving other motor skills, but no apparent reasons exist for them not being applicable to piano playing as well): it is better to practice rapid passages at a fast speed as near as possible to the required speed, and not engage in slow practice. Practising rapid passages in varied rhythmical patterns can be counterproductive. In the acquisition stage of learning a piece containing polyrhythms distributed between the hands, massive interference occurs, because the motor program can handle only one underlying temporal construct; therefore some (mental) strategy, at least initially, must be contrived to link the rhythms in both hands to some common temporal basis. Students should not refrain from attempting difficult rhythmical constructs like playing *rubato* proper, as each hand can be thought of as regulated by a

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rather flexible internal clock; thus the motor system is equipped for dealing with such problems. Because of a "coupling" of the muscles in the dominant hand to the corresponding muscles of the non-dominant hand via the muscle-selection parameter in the generalized motor program, the simultaneous execution of figurations which are mirror images of each other with respect to the keyboard lay-out is a relatively easy matter. Simultaneous leaps in opposite directions can be controlled by the same generalized motor program; even if different distances are traversed, the hands should reach their destinations simultaneously, because different overall-force parameters can be selected for each limb. It is better to practice hands together rather than apart, because motor programming of the movement patterns in a particular hand may be quite different for the hand playing in the two-handed context, than for the hand playing on its own. When the non-dominant hand only has a simple accompaniment to deal with, practising hands apart would not make too much of a difference. Variable practice should produce improved learning - although it is not certain *what* should be varied - due to the fact that more effective schema are formed this way. Because massed practice induces greater variability in the task and/or causes the relevant information-processing to be more exhaustive, it is almost as effective as distributed practice, even though performance during the task deteriorates because of fatigue. Thus the fact that quality of performance will probably decrease during long practising sessions should not discourage students from practising hours at a time, because a decrease in performance quality does not necessarily imply a decrease in learning. Similar reasons hold for random practice being generally more effective than blocked practice; a deterioration in performance being associated with random practice as well. Practising a part of a piece in isolation, may so change the programming of the part, that it is no longer the same as it is in the context of the total piece; therefore at least some practice of the piece as a whole should be included in a practice session. Practising parts in isolation of piano pieces with predominantly serial characteristics, can be beneficial; it is not certain whether this will always be the case for pieces with predominantly continuous skill characteristics. Mental practice can in a sense be considered as fulfledged practice, because the generalized motor program controlling the task is executed as usual, the only difference being that the gain is turned down, so that physical movements are not observable.

If action systems theory is correct in its presumption that the motor systems theory application of the information-processing computer metaphor to human motor behaviour is invalid, and that the motor programming notion is wrong, then many of the arguments stated above could loose their status as premises based on scientific theory, which is the very reason for endorsing their inclusion in a strategy for practice. Various arguments presented by action theorists to support their view that motor systems theory has incorrectly approached the study of human motor behaviour, indeed give rise to some rather disquieting questions regarding the validity of motor systems theory which remain unanswered. These arguments include the fact that many laboratory researchers have studied motor skills which are irrelevant for everyday skilled human motor behaviour in an impoverished controlled

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environment; the inability of traditional motor systems theory to account for human use of tools, in spite of the fact that many laboratory experiments require some sort of tool use; and the complexity and cumbersomeness, if not the practical impossibility, of accounting for relatively simple movement activities through theoretical constructs like control systems and the motor programming notion. Underlying this complexity is of course the description by motor theorists of human movement in kinematical, kinesiological and/or dynamical terms.

If action systems theory is also correct in its notion that human motor activity should rather be described in terms of functionally-defined postures and movements that constitute interacting action cycles and action systems, then learning without repetition - a *most* exciting prospect! - should be at the order of the day; thus, after completing the functional organization of whatever postures and movements serve to get the job done, the actor should be able to give a proficient performance of the skill he was required to master. Approaches advocated by certain piano pedagogues seem to have much in common with action theory concepts; especially the theorizing of Abby Whiteside stands out in this regard. Unfortunately, it appears to be extremely difficult to extract from the former some suggestions of how motor skill learning under such a quasi-action approach would actually take place and what the conditions would have to be to cultivate such learning; there appears to be some uncertainty about what happens between the learner coming to the piano for the first time, and the final, coordinated result. Of course, it may also be possible, as pointed out by some theorists, that action systems theory is inherently incapable to account for motor learning due to its shunning of cognitive structures.

Although it is undisputable that action systems theory makes a substantial contribution in pointing out the fallacies of the motor systems approach to motor control and learning, its own premises on how human movement occurs still need to be tested in most areas. Uncertainty exists, especially in the area of highly-skilled motor behaviour, about how movement takes place according to the action view. It is also not known how the functional nesting of postures and movements into action cycles, for the basic acts, occurs. Research needs to be done, furthermore, on how treatment of the senses as perceptual systems, will influence the conception of piano playing that is currently in vogue; the sight-reading field should also gain from such investigations.

It can be taken for granted that years of research efforts by the motor behaviour science community lies ahead for the motor systems and action systems approaches to motor control and learning as separate orientations of study, as well as for the controversy in which these perspectives radically oppose each other in explaining motor control and learning. (Some theorists feel that comparison between the two theories is not possible because they operate at different levels of analysis). Much more research, which directly involves piano playing, is necessary from both the

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motor and action viewpoints, before any definitive recommendations can be made on which of the two approaches, or what sort of synthesis (if any), can be used as a scientifically-verified basis for piano-technical instruction and learning. Although the motor perspective is an established one, research findings pertaining to piano playing appear to be very scant, and experimental results based on the action approach seem to be virtually non-existent. How experimentation in the action sense should be carried out with respect to piano playing is an open question; it should nevertheless be well worth the effort to attempt establishing a scientific basis with some sort of generality for the ideas of Whiteside and others that exude so much promise on paper.

Finally, it should be emphasized that the present study has clearly shown that matters of motor control and learning in general, and piano playing in particular, are neither simple and straightforward, nor very predictable. This has some obvious, though rather significant, implications for the practice of piano-technical skills: if a pianist manages to master a particular problem, this does not necessarily mean that he mastered it because he employed a strategy based on the correct theoretical principles; it could just as well imply that he unwittingly applied in his practising, some aspects of what is really the correct theoretically-based strategy. And if a pianist practises the piano, without success, according to a strategy planned along the lines of all the theoretical premises known to the pianist and teacher, all is not necessarily lost; it is indeed possible that some or all of these premises may be wrong, requiring some further experimentation or search for new or improved theoretical principles. It is well known that narrow-mindedness in any field of study should be avoided at all costs; narrow-mindedness or adherence to traditional beliefs and habits, simply because they have been in use for decades or even centuries, appear to be profoundly misplaced in the field of piano playing.

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