Setting the scene

1 Motor development in children at risk: two decades of research in experimental clinical psychology

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INTRODUCTION

This chapter discusses some core issues in the study of normal and deviant motor development that have been addressed in experimental clinical psychology during the last 20 years. I try to indicate how longitudinal and cross-sectional approaches may be interrelated in interdisciplinary studies on motor development and how ethological observations and information-processing experiments may both have their function in the study of motor development in normal children as well as in children at risk. The following points are discussed:

(1) Why study motor development in the context of research on neurobehavioural relationships?
(2) Is there an optimal strategy in the longitudinal study of motor development? How can an optimal balance be obtained between observation and experiment in research on motor development?
(3) How may intra- and interdisciplinary studies complement each other?

To begin with, I discuss briefly the rationales for studying motor development.

WHY STUDY MOTOR DEVELOPMENT?

Motor development in humans can be studied for at least two reasons (see Kalverboer & Hopkins, 1983).

Motor development studied in its own right

What are the relevant motor phenomena in the various phases of development? How are motor functions controlled (e.g. the role of visual and proprioceptive feedback in movement control) and what are the processes of organization and reorganization during motor development? Previously such studies on motor development per se were of a global and descriptive character (e.g. in terms of milestones or the observation of complex motor performances as made in such tests as the Lincoln–Oseretsky (Sloan, 1955). Now, they often focus on specific functions such as the maintenance of posture (Woollacott, Chapter 6, this volume), goal-directed reaching and grasping (von Hofsten, Chapter 7, this volume), locomotion (Provine, Chapter 4, this volume) or on the development of specific skills such as tool use (see Connolly and Dalgleish, Chapter 12; Vauclair, Chapter 13, this volume) and handwriting (see van Galen, Chapter 14; Søvik, Chapter 15, this volume). In studies of children at risk, interest is often focused on how biological factors, in particular the condition of the central nervous system, may affect motor development (Largo, Kundu and Thun-Hohenstein, Chapter 16; Michelsson and Lindahl, Chapter 17; Touwen, Chapter 2, this volume).

Motor behaviour studied as a carrier of adaptive functions

Functions such as signalling, visual orientation, exploration, or play can be studied only by careful observation of movement patterns (Papoušek and Papoušek, Chapter 9; Butterworth and Franco, Chapter 10, this volume). The form of such patterns is important in that it may reveal their adaptive functions as well as give indications of the quality (optimality) of the performance. Studied in this way, movements can serve as an indicator of the child's level of cognitive, social and emotional functioning (see Alberts, 1990). It may also enable the detection of hidden processes such as perceptual discrimination, short- and long-term memory and decision making (see Geuze, Chapter 19; Henderson, Chapter 18, this volume), typically using experimental techniques based on the reaction time paradigm. Such studies have two global aims:

(1) To understand deviant motor development in terms of information-processing deficiencies.
(2) To study information processing by means of analysing movement patterns in various stress-inducing conditions.

Both approaches can be used in the study of motor development in children with problem behaviour (attention deficit–hyperactivity disorder/clumsiness), and children at risk (prematurity, congenital hypothyroidism), as well as in the study of motor development in the normal child. Combining studies in normal and risk populations corresponds to Sroufe & Rutter's (1984) depiction of the field of developmental psychopathology: deviance cannot be understood without knowledge of normal development, which in turn can benefit from insights obtained in the study of clinical cases (see also Kalverboer, 1990, pp. 1–2).

Observations and models

Since about 1950, interest has increased in the longitudinal study of the development of the nervous system and behaviour. This was triggered by the intensively debated issue of minimal brain dysfunction (MBD), and by the notion that so-called soft neurological signs should be taken seriously.

Behavioural studies concerned with MBD were initiated by ethologically biased paediatricians and psychologists. Quantitative ethology was introduced into developmental medicine by Ounsted (1955) in his study of epileptic-hyperactive children and by Hutt, Hutt & Ounsted (1965) in their work on brain-damaged and autistic children. Our studies were initiated by the concept of MBD and guided by the opinion expressed in Ounsted's preface to the study by Kalverboer (1975) that 'We must know our own animal if we are to be good ethologists' and that 'for those interested in the brain and its development quantitative ethology is the best, and indeed the only, way in which the actual workings of the untrammelled brain can be studied properly'.

In my laboratory, studies on motor development are rooted in an ethological approach to neurobehavioural relationships. In this programme there has been a progression from detailed observations of the child's movement patterns in the free field and in specific task conditions triggered by approaches in ethology (Kalverboer, 1975; Kalverboer & Brouwer, 1983) to experimental studies of goal-directed movements, largely structured by information-processing theory (Schellekens, Scholten & Kalverboer, 1983; Schellekens, 1985; Geuze & Kalverboer, 1987; Van Dellen, 1987; Van Dellen & Geuze, 1988). This line of progression is illustrated in the following section; it focuses on motor development and information-processing capacities in the age range 5 to 13 years in normal children as well as in clinical groups.

Free field observations in the laboratory

The first series of observational studies concerned neurobehavioural relationships at preschool age. The free-field behaviour of preschool children was observed under different laboratory conditions: with or without the mother in a novel room, with attractive or non-attractive toys (Kalverboer, 1975). Behaviour was analysed in terms of predefined categories such as locomotion patterns, body postures, manipulation of body and fixtures, gestures, visual fixations and scanning patterns. Such categories allowed for a refined analysis of functional entities such as exploration, contact and play behaviour. Neurobehavioural profiles were obtained, expressing the connection between the child's neurological condition and free-field behaviour. In general, neurobehavioural relationships strongly depended on the particular situation: mildly stressing and boring conditions most clearly distinguished between the neurologically impaired and the optimal subjects.

These free-field observations facilitated the design of the first experimental studies on children's visuo-motor behaviour. Such observational experiments provided a descriptive framework for the interpretation of specific functions in terms of the total behavioural repertoire. Furthermore they gave indications about the conditions which were most sensitive for the distinction between neurologically optimal and suboptimal children. The approach may be illustrated by an initial perceptuo-motor experiment consisting of a block-sorting task (Kalverboer & Brouwer, 1983).

In this task an attempt was made to combine approaches from experimental psychology (reaction time measurement in systematically varied task conditions) with detailed observations of the child's behaviour. Children had to put differently shaped blocks through holes in the top of a box in conditions with or without time pressure. Visuo-motor behaviour was analysed from video recordings, in terms of descriptive categories, which represented the most salient aspects of the children's repertoire for this task.

Behavioural categories were grouped in two ways:

(1) In terms of spatio-temporal variables (e.g. near table, during transportation or at insertion).
(2) In terms of the degree in which they reflected aspects of the child's information processing (e.g. selection or decision making).

This task illustrates how detailed observation can give some insight into the child's information processing. Categories such as 'correction at grasping' or 'visual scanning movements before taking a block' could indicate how selection and decision processes played a role in the child's behaviour. Together with reaction time measurements, refined analyses of observational data clarified how movement organization relates to task efficiency. Such analyses also indicated how children changed their strategies in order to cope with information overload.

One main result was that movement organization was strongly affected by time pressure, becoming more simple and less flexible (e.g. fixated angles between under arm, upper arm and shoulder) under time pressure than in relaxed conditions. Few differences in movement efficiency and sensitivity under stress were found between neurological subgroups. They were related mainly to the child's motivation and interest in the task.

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Reaction time experiments

In an experimental study such as that mentioned above, first indications about the child's information processing can be obtained by close observation of complex movement patterns. However, to study motor behaviour more systematically from an information-processing viewpoint, tasks have to be structured on the basis of explicit information-processing models, so that specific task variations represent specific aspects of information processing (see Fig. 1.1).

On the basis of such models, subsequent reaction time experiments were designed to reveal the effects of deficiencies in specific stages of information processing on children's movement organization. One of the first attempts in my laboratory was an experiment involving a serial movement task, applied to normal children in the age range 5 to 12 years (Schellekens & Kalverboer, 1983).

In this task, cylindrical blocks had to be transported to one out of a number of boxes of a corresponding colour. The main question concerned anticipation: how far are children able to make use of precueing about the position of the target in organising their movements. In the basic condition the target colour was on the top of a block, so that it could not be seen before the block was picked up from the bottom of a pile in a tube. In the anticipation condition the colour was at the side of the block so that it could be seen during a previous transportation movement.

Older children took profit from precueing (shortening their reaction times), whereas younger children did not. The youngest even became disorganized when they had to anticipate subsequent task components and lost time in the precueing condition.

A large series of experimental studies followed. These studies, based

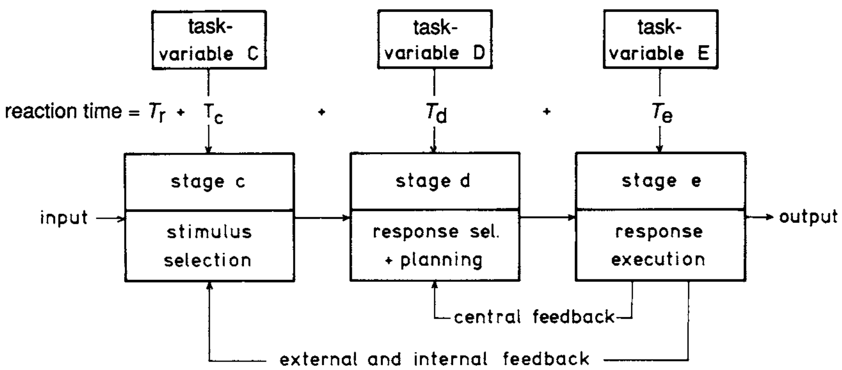

Fig. 1.1. A hypothetical model of information processing. sel., selection; T_R, total reaction time; T_c, T_d, T_e, reaction times for different phases of information processing.

mainly on information-processing theory, focused chiefly on so-called structural factors in information processing that may affect normal and deviant motor development. Structural information-processing models contain processes, such as stimulus processing and feature extraction (Sanders, 1983), decision making and motor organization. Such models have become increasingly more differentiated (see e.g. Theios, 1975). Aspects of information processing can be affected selectively by task manipulations, such as varying the number of choices and precueing. In addition, these studies reflected prevailing models of motor control such as open and closed loop control. The integration of these models required detailed registrations of movements.

As stated by Schellekens (1985, p. 109) 'The employment of experimental paradigms combined with detailed recordings of motor activities' can 'provide relevant data for tracing biological and psychological processes which are active during the planning and execution of movements'. Selspot movement registrations allow for analyses in terms of movement trajectories, velocities and acceleration/deceleration patterns (see Figs 1.2 and 1.3). Such analyses permit the identification of movement elements, which assist in interpreting deviances and age differences in terms of inefficient programming and execution of movements.

Globally, the results obtained showed clear-cut age differences (age range 5 to 9 years), indicating an increase in information-processing capacity with increasing age (Schellekens, 1985), a finding later

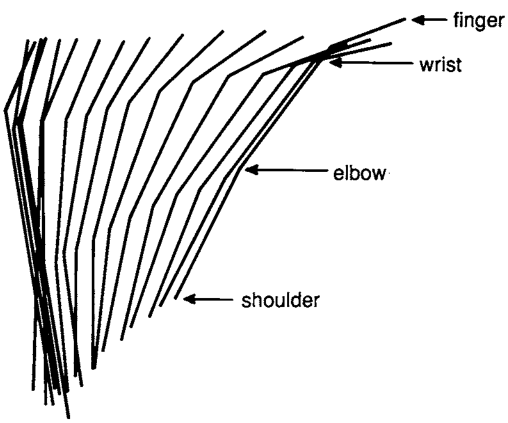

Fig. 1.2. Stick diagram of a fast goal-directed arm movement from a Selspot recording. (Reprinted with permission from *Journal of Child Psychology and Psychiatry*, **1**, J. M. H. Schellekens, C. A. Scholten & A. F. Kalverboer: Visually guided hand movements in children with minor neurological dysfunction: response time and movement organization. Copyright © 1983, Pergamon Press Ltd.)

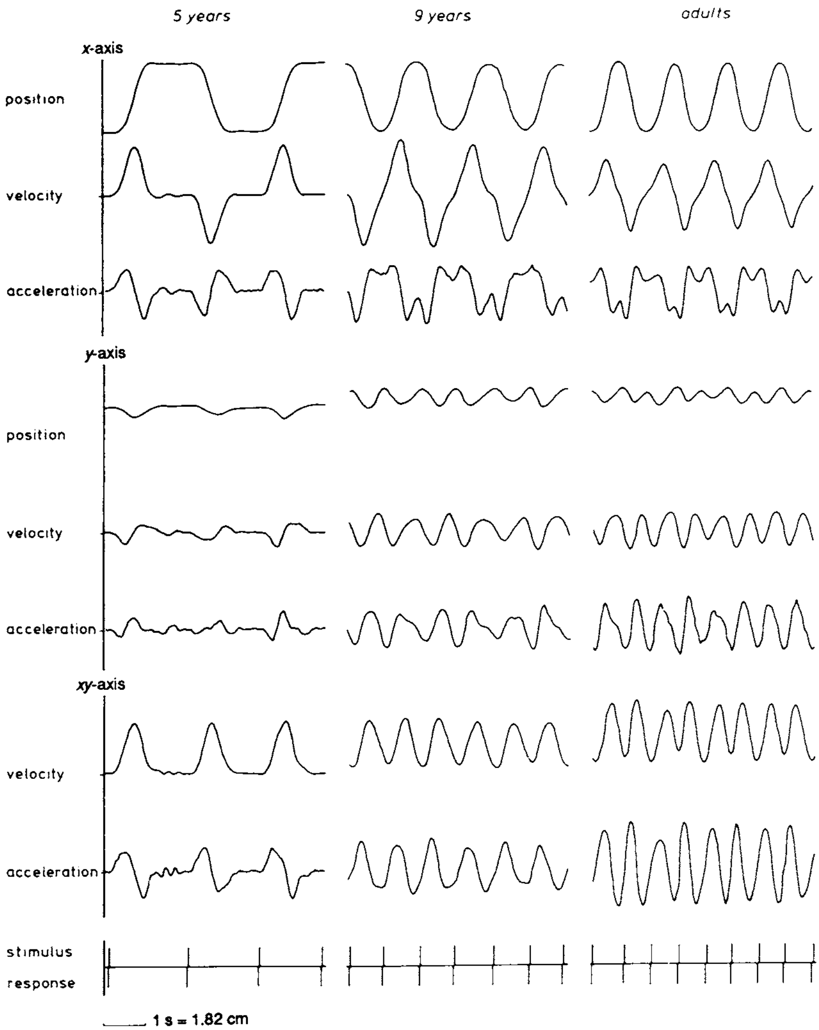

Fig. 1.3. 'Selspot' finger movement recordings of subjects at the age of 5 years (left), 9 years (middle) and adult age (right) in the self-paced condition of a tapping task. Position, velocity and acceleration curves on the x-axis (upper part) and y-axis (middle part), and velocity and acceleration curves on the joined xy-axes (lower part). On the bottom line the time of the stimuli (upward peaks) and the responses (downward peaks). (From Schellekens 1985.)

confirmed by Van Dellen (1987). This increase is related mainly to automatization of movement control and to a much lesser extent to an increase in the speed and organization of mental processes. Also the structure of the movements changed in relation to age; young children showed distinct distance covering and homing phases in these experiments, unlike older children and adults where a separate homing phase is lacking due to 'smooth visual braking replacing terminal correction' (Biguer, Jeannerod & Prablanc, 1982). In general the assumption is supported that children use more serial strategies of information processing than do adults (see also Connolly, 1970).

Children with minor neurological dysfunctions (MND) showed smaller durations and less accuracy of movements. They have more movement elements, but it is still unclear whether this is due to more corrections or to involuntary neuromuscular activity (Schellekens *et al.*, 1983).

Van Dellen (1987) studied, in children in the age range 6 to 13 years, how the execution of fast goal-directed hand movements develops in relation to movement difficulty. He concluded that movement execution is more accurate in simple than in difficult movements, and in older than in younger children. As a result, in older children fewer movement corrections are required. His data on the development of goal-directed reaching confirmed the findings of Hay (1979) of a developmental discontinuity around 7 to 8 years of age.

In a second series of experiments in four groups of children (aged 6 to 13 years) and in adults, Van Dellen *et al.* studied the ability to perceive and process information simultaneously, with the application of reaction time experiments and precueing techniques. He concluded that the ability to handle additional information improves with age. A third series of his experiments concerned developmental clumsiness. After a careful stepwise selection procedure (see Van Dellen, Vaessen & Schoemaker, 1990), groups of clumsy children and controls were identified on the basis of teacher ratings of motor behaviour and subsequent examination on the Test of Motor Impairment (Stott, Moyes & Henderson, 1984).

Applying Theios' (1975) model, Van Dellen studied motor response processing in clumsy children. He confirmed the hypothesis that the process 'response determination' contributes in particular to the slow performance of clumsy children, but could not confirm the hypothesis that this process also affected the inaccuracy of their performance. Such children, as compared with controls, have more problems in translating the stimulus code into the response code (Van Dellen & Geuze, 1988).

These experimental procedures may provide us with refined insights into how aspects of information processing may affect the planning and execution of goal-directed movements. However, questions remain with respect to the ecological validity of laboratory data.

Experimental observations in the field

For good reasons, we increasingly moved away from the study of the freely moving individual in his or her natural habitat to the measurement of specific reactions in highly controlled experimental conditions. Guided by information-processing theory, we had been able to detect some essential features of perceptuo-motor behaviour in younger *vs* older and in clumsy *vs* non-disturbed children. However, the movements studied in these laboratory settings were relatively simple. The general applicability of results seemed questionable.

Further exploration of the ecological validity of these experiments was instigated by Vaessen (Vaessen, 1990; Vaessen & Kalverboer, 1990) in his studies on hyperactive and clumsy children. He designed complex double tasks such as walking over a horizontal bar under various cognitive load conditions, and crossing a street in easy and difficult conditions. In these daily life conditions, clumsy children were impaired in the organization of their motor behaviour, in particular in higher load conditions.

Experimental approaches discussed so far typify our research on motor development. Recently these approaches have been applied in various longitudinal (experimental) studies on clumsy children (R. H. Geuze & J. M. A. Börger, unpublished results) and in follow-up studies on children, treated early for congenital hypothyroidism (L. Kooistra *et al.*, unpublished results). This raises a question about the role of longitudinal and cross-sectional approaches in the study of motor development.

Longitudinal and cross-sectional approaches: how can these approaches make a contribution to the study of motor development?

The longitudinal approach is indispensable in the study of:

(1) Motor behaviour as a process of continuous organization and reorganization, e.g. to study the role of visual feedback in the course of the development of goal-directed reaching (see von Hofsten, Chapter 7, this volume) or the effect of physical growth on motor coordination.
(2) Individual differences in motor development.
(3) The relationship of early biological and environmental (risk) factors to subsequent motor development.

Cross-sectional studies may be indispensable for the following types of question:

(1) What are the prerequisites in terms of information processing for certain motor performances? The cross-sectional design may allow for in-depth studies at particular ages, which can be integrated into later follow-up studies.
(2) What is normal at a certain (chronological or maturational) age? Normative data cannot easily be obtained in longitudinal studies because of attrition or specific cohort differences.

Table 1.1. *Comparison of research designs*

Microgenesis[a]	Cross-sectional	Longitudinal
Not in real time	Considered to represent real time	In real time
Extremely short	Relatively short	Long
Study of microprocesses which are expected to *simulate* developmental processes	Shortcut, considered (to some extent) to represent individual development	Following individual development
Experimental manipulation to study 'natural' changes	Shortcut to 'represent' natural change	Natural 'manipulation' (change) generally no experimental manipulation
No direct interest in the 'natural history'. *No detection* of mechanisms. At best such mechanisms can be suggested, which have to be 'checked' in real time longitudinal studies	Little interest in detecting the natural history, some interest in mechanisms. No possibility to trace individual courses	Interest in 'natural history' and in mechanisms (intermediate factors) Factors *contributing to*, causal for
Saves money and time (much)	Saves money and time (moderate)	Expensive
No study of natural transitions (of a complex character) at least if not part of the 'underlying' theory	Does not allow for the detection of complex transition patterns (elements different time schedule) (in essence correlational designs)	Allows for the study of complex transitions (e.g. as an effect of sequences of events) and tracing individual developmental courses
Indicated If there exists a clear theoretical basis concerning mechanisms, which can be studied in a micro-experimental setting	If there are clear notions about the possibility of representing real life processes and/or if one is not interested in such processes	If knowledge of an individual's natural history and of exact time relationships is required and knowledge about causal relationships has still to be obtained

[a] This is the short-term adaptation to sudden changes in the environment, which are thought to simulate long-term adaptational processes as they occur in ontogeny.