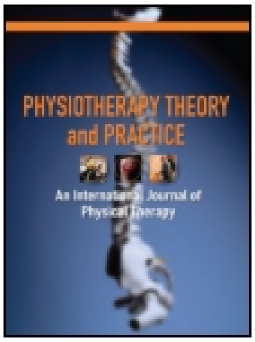

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EDITORIAL

Motor control issues and clinical applications

In the past decade, research in motor behaviour has shown an emerging interest in the mechanisms and organisational principles involved in the control of actions. This new focus has also taken a more ecological view of actions, recognising that what is organised is not simply a collection of movements at various joints. This perspective is also of critical relevance for clinicians. Of particular interest are the features of the control system that distinguish 'movements' *per se*, such as extending the elbow, from 'actions', such as reaching to pick up a cup. One such distinctive feature of action control is a goal or intention which is thought to influence the characteristics of control and coordination to achieve specific functions (Reed, 1988). There also seems to be growing evidence to support the idea that control of actions is context-specific (Marteniuk, MacKenzie and Leavitt, 1988). Task context is likely to be determined not only by information in the environment with which the performer must interact, but also internal information about the performer's own body morphology and the capacities and limitations of his or her motor system. Another feature of note is that most everyday actions call upon muscles and limb segments to operate cooperatively, so that control of trunk posture may be a necessary component in achieving the overall goal of picking up a cup. Studying actions and not discrete movements is therefore of key importance. Indeed, there is a trend in motor control research, and in some rehabilitation settings, for determining not only whether an action goal has been attained successfully, but how the performer's body segments are coordinated in space and time, from the initiation of the action to the final goal achievement. This is referred to as kinematic analysis. What follows is a discussion of some of the ways in which these key issues and methods in current motor control research might guide assessment and rehabilitation of motor dysfunction.

Real-world motor skills

Ecological psychology has played a major influence in directing researchers towards investigations of natural actions and away from laboratory-based, simple movement tasks. In addition, there has been a greater emphasis on understanding interactions between the performer and the environment in which actions are performed. This approach has evolved from Gibson's (1966) ideas about direct links between perception and action and has been extended in the so-called 'action' perspective described by Turvey and colleagues (Turvey, 1977; Kugler, Kelso and Turvey, 1980; Kugler and Turvey, 1987). The importance of assessing actions that are part of everyday experiences in a rehabilitation setting is elaborated with respect to gait by Rozendal (1989), who advocates testing walking ability over uneven terrain, negotiating stairs and obstacles, and over a variety of distances. Similarly, assessment of upper-limb actions involving reaching and grasping might emphasise manipulating a variety of tools and objects commonly encountered in everyday life. Van der Weel, van der Meer and Lee (1991) have demonstrated the influence of contextual cues in the assessment of motor dysfunction in children with cerebral palsy. They found that the range of supination and pronation at the elbow joint was significantly greater when the children performed a drum-beating action compared with the same movement performed with a lever, devoid of meaningful task context. Improvements in motor control represented by smoother arm movements have also been demonstrated in patients with apraxia when reaching to pick up a real spoon versus a rod used as an imaginary spoon (Charlton, Roy, Marteniuk and MacKenzie, 1988). These findings would suggest that critical cues about task function are provided by real objects, and that in certain neurological conditions, individuals may be unable to adequately access such cues or to organise the motor system responsible for producing appropriate actions. Furthermore, conventional measures of isolated limb movements may provide an incomplete picture of patients' capabilities for actions, given appropriate contextual cues.

A systems approach

Bernstein's (1967) notion of a coalitional style of control has been influential in recent theories of motor control (Arbib, 1985; Reed, 1988; Schmidt, 1988; Turvey, 1977). The complexity of everyday actions, evident in sports skills, the manipulation of kitchen implements and industrial tasks, is characterised by the regulation of many planes of movement and a multitude of muscles spanning numerous joints. Certainly, the idea of muscle-specific commands has lost considerable favour. A broadly accepted, alternative view is that muscles are organised in such a way that they are constrained to act as a unit for a given action. Consistent with this explanation, Ada, O'Dwyer and Neilson (1993) have proposed that in hemiplegia following a stroke, the organisational structure responsible for coupling the movements across multiple joints is likely to be disrupted. Moreover, their findings demonstrate that, in a sitting-to-standing action, synergic couplings between the hip and knee joints become stronger as rehabilitation progresses. Thus, while most clinical descriptions of recovery of motor function suggest a progression from primitive synergies towards more independent control of segments (e.g. Brunnstrom, 1970), Ada and colleagues' work suggests that tighter coupling of synergies across multiple joints typifies efficient coordination. The authors note, however, that the apparent contradiction in views is resolved if one thinks of 'independent control' of individual segments as the ability to rapidly assemble, disassemble and reassemble functional units in another synergy, depending on particular task conditions.

The notion of functional units of organisation for action also calls into question the use of electromyographic (EMG) biofeedback in rehabilitation where patients are required to contract and relax isolated muscles or muscle groups to improve muscle strength. Instead, it may be more desirable that biofeedback be used to train the total pattern of the activity within a meaningful, goal-directed task. Mulder and Hulstyn (1984) cite an example of this approach in gait retraining. Patients received feedback about EMG activity of their own dorsiflexors as well as the therapist's dorsiflexors during walking, so that they had to match these signals to improve the timing of their walking.

In an elegant model explaining the control of complex actions involving many limb segments, Arbib (1985) describes combinations of interacting motor schemas, organised in a coordinated control programme. Arbib uses the model to explain the interdependence of components of prehension, including a component for transporting the arm towards an object and other components to orient the hand and to preshape the fingers to form an appropriate grasp around an object. This model not only simplifies the organisation of output of the motor system but proposes a linkage between sensory information and motor schemas. For example, information about object location may be relevant to the schema for transport of the arm to the object, while information about object shape and size may be pertinent for the grasp schema. This emphasis on understanding the links between perception and various components of action control is potentially useful in clinical practice. For example, in the rehabilitation of feeding actions, training instructions may emphasise pertinent sources of information (e.g. the orientation of a spoon handle resting in a bowl), essential for governing the control of specific components of an action (orienting the hand in order to grasp the spoon).

Arbib's model suggests a number of levels of systems and subsystems sharing in the control process. Several other authors have also urged us to consider movement dysfunction from a systems approach (Kamm, Thelen and Jensen, 1990; Woollacott and Shumway-Cook, 1990). This approach to assessment might take account of whether, when lifting a heavy suitcase, the head and eyes are initially oriented towards the case; and also whether the muscles of the feet, legs and trunk are activated in a particular synergic pattern to stabilise the body while the focal action of the upper limb is achieved.

In addition to assessment considerations, the understanding of motor control as a systems model also has implications for rehabilitation strategies. It is not an uncommon practice in the rehabilitation of motor impairment, particularly with infants, to adopt a 'stages' approach, with achievement of head control seen as a prerequisite for the development of manipulative skills. Ada and colleagues (1994) demonstrate the importance of a systems approach in the rehabilitation of upper-limb function, suggesting that there are likely to be benefits from incorporating postural adjustments early in the training of reaching and grasping by practising in a variety of sitting and standing postures.

The measurement tool

In order to describe actions in three-dimensional space, researchers have directed their attention to the study of trajectories to characterise the movement process. Trajectories are represented using kinematic measures such as the displacement or path of a limb in completing an action, as well as various derivatives of displacement such as velocity and acceleration. The advantage of such measures over more conventional measures of motor dysfunction (such as range of motion and assessment of independence in performance of daily living skills) is that the entire movement can be quantified in terms of the spatial and temporal characteristics of various limb segments. For example, in reaching and grasping, it may be of interest to determine the straightness of the path of the hand, the smoothness of the reach, and the coordination between movement at the shoulder and elbow joints.

Use of kinematic measures of gait, prehension, writing and other tasks, sometimes coupled with electromyographic and kinetic data, is becoming increasingly common in the assessment of movement dysfunction (Ada et al, 1993; Ada and Westwood, 1992; Charlton, 1992; Jeannerod, 1986; Lough, 1987; Kluzik, Fetters and Coryell, 1990; Mulder and Geurts, 1991; Olney, Costigan and Hedden, 1987; Phillips, Stelmach and Teasdale, 1989, 1991; Poizner et al, 1990; Rogers, Deming Hedman and Pai, 1993; Trombly, 1992). The availability of more sophisticated measurement tools provides a means of quantifying the behavioural changes resulting from damage to the neuromuscular system and charting of patient progress during rehabilitation. Improvement may be observed in smoother, more direct and less variable trajectories, depending on the goal of the task.

The ability to describe movements accurately, however, is not sufficient. The challenge for therapists is to examine movement dysfunction within a sound theoretical framework so that outcomes can be interpreted in the light of current understanding of control systems. For example, trajectories of the hand during reaching characteristically show a single acceleration and single deceleration phase as the hand is transported to the object under feedforward (pre-programmed) control. Following this, there is a period of minor adjustments in speed as the hand 'homes in' on the object under feedback guidance. Comparisons of trajectory profiles of patient groups with typical reaching trajectories may provide insight into underlying difficulties in the use of feedforward and feedback control of actions. By way of illustration, jerkiness of the hand seen in apraxic patients' reaching (multiple acceleration and deceleration phases) may be explained by inaccurate pre-programming or inappropriate use of feedback to guide the hand during the entire reaching action (Charlton, 1992).

The increasing emphasis on theory-based interpretation of clinical findings must be balanced with critical reasoning about functional motor outcomes: 'Is the treatment achieving what is needed for this patient?' (Burgess, 1989). Fetters (1991) urges therapists not to focus solely on improvements in kinematic measures but to consider the functional significance of such changes. She describes a study in which effectiveness of an intervention was demonstrated by improvements in the smoothness of prehension in children with cerebral palsy, but that this was achieved in some subjects at the expense of overall head and trunk control. Similarly, efficiency in ambulation in children with cerebral palsy must take into account not only the achievement of kinematic patterns like those of normally developing children, but also the physiological costs of such achievements.

Specificity of control

As noted above, the use of kinematic measures has provided an important tool for understanding the organisation and control of actions. The importance of trajectory profiles is that, if the shapes remain invariant over different task conditions, this is support for a motor control system that is both general and abstract (Marteniuk et al, 1988). One idea is that planning and control for a particular class of actions can be achieved by simply scaling up or down the speed of movement, creating a scalar family of trajectories. However, there is considerable evidence being gathered from studies of adult reaching and grasping actions, that various task constraints, such as the size, texture and fragility of the object to be grasped, lead to quite different trajectory shapes, reflecting different underlying control processes. For example, work by Marteniuk and colleagues (1987) suggests that proportionately more time is spent in deceleration when reaching to pick up small objects compared with larger ones. Similarly, trajectory shapes are affected when the task requirements change, such as after reaching to pick up an object it is either placed precisely or thrown into a box. In these tasks, in the initial reaching part of the action, a greater proportion of time is spent in deceleration for placing compared with throwing. Similarly, the control characteristics of other components of prehension, the grasp, have been shown to be sensitive to object features such as size and orientation. Thus, examination of the shape of the trajectories is important and it is proposed that different shaped trajectories reflect different underlying control processes. It would appear then that there are a range of structural properties of objects, as well as task goals (that is, what kind of task is to be performed with the object), that constrain the way in which actions are planned and controlled. This is evidence against the idea of a general motor programme for all reaching actions. What seems more likely is that programming of actions is relatively task- and object-specific.

At present in our laboratories (Charlton et al, in prep.), we are investigating the possibility that if children with intellectual disability do not have the cognitive ability to perceive, integrate and use object and task information, they may resort to such a generalised programme. This would be reflected in velocity profiles for reaching actions that are similar in shape, despite object and task differences. Furthermore, these trajectories would be different in shape to those of normally developing children.

The message for clinicians here, too, is that assessment and rehabilitation of movement disorders may need to be task-specific. This position has been argued by a number of authors (van Vliet, 1993; Malouin et al, 1992; Carr and Shepherd, 1987) and has been elaborated by Ada and colleagues (1994), who have developed a number of task-specific strategies for the rehabilitation of upper-limb actions after brain damage. The authors propose that opportunities be given for patients to match their performance to the characteristics of the task and the environment. By providing a variety of objects and task goals, patients are encouraged to explore both the environmental and physiological constraints that govern their performance. They may need to relearn how the hand must be oriented, what fingers must be used to grasp the object and how to control for direction and distance. Furthermore, training tasks and objects can be selected to constrain postures and movements and to promote more desirable control. For example, 'when a child has difficulty controlling the orientation of the hand and limb and reaches persistently with the shoulder internally rotated and the forearm pronated . . . an object or a task should be chosen that demands a relatively externally rotated and supinated approach' (Ada et al, 1994, p. 254).

Summary

In everyday clinical practice, wholesale acceptance of unproven methods based on contemporary motor theory is neither advocated or desired. An appropriate model, however, is for therapists to be informed about current thinking, to judiciously select and implement new theoretical applications, and to observe, measure and report outcomes in professional and scientific journals. In this way, therapy will be advanced by theory. Further, this approach can drive new theoretical enquiry to promote greater understanding of the motor control system.

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References

Ada L, Westwood P 1992 A kinematic analysis of recovery of the ability to stand up following stroke. Australian Journal of Physiotherapy 38: 135–142

Ada L, O'Dwyer NJ, Neilson PD 1993 Improvement in kinematic characteristics and coordination following stroke quantified by linear systems analysis. Human Movement Science 12: 137–153

Ada L, Canning CG, Carr JH, Kilbreath SL, Shepherd RB 1994 Task-specific training of reaching and manipulation. In: Bennett KMB, Castiello U (eds) Insights into the reach to grasp movement, pp 239–265. North-Holland, Amsterdam

Arbib MA 1985 Schemas for the temporal organisation of behavior. Human Neurobiology 4: 63–72

Bernstein N 1967 The coordination and regulation of movements. Pergamon Press, Oxford

Brunnstrom S 1970 Movement therapy in hemiplegia: A neurophysiological approach. Harper and Row, New York

Burgess MK 1989 Motor control and the role of occupational therapy: Past, present, and future. American Journal of Occupational Therapy 43: 345–348

Carr JH, Shepherd RB (eds) 1987 Movement science: Foundations for physical therapy in rehabilitation. Heinemann Physiotherapy, London

Charlton JL 1992 Motor control considerations for assessment and rehabilitation of movement disorders. In: Summers JJ (ed) Approaches to the study of motor control and learning, pp 441–467. North-Holland, Amsterdam

Charlton JL, Roy EA, Marteniuk RG, MacKenzie CL 1988 A kinematic analysis of prehension in apraxia. Proceedings of the 18th Annual Meeting of the Society for Neuroscience 14: 1234

Charlton JL, Ihsen I, Oxley J (in prep.) Kinematic characteristics of reaching and grasping in children with Down syndrome

Fetters L 1991 Measurement and treatment in cerebral palsy: An argument for a new approach. Physical Therapy 71: 76–79

Gibson JJ 1966 The senses considered as perceptual systems. Houghton-Mifflin, Boston, MA

Jeannerod M 1986 Mechanisms of visuomotor coordination: A study in normal and brain-damaged subjects. Neuropsychologia 24: 41–78

Kamm K, Thelen E, Jensen JL 1990 A dynamical systems approach to motor development. Physical Therapy 70: 763–775

Kluzik J, Fetters L, Coryell J 1990 Quantification of control: A preliminary study of effects of neurodevelopmental treatment on reaching in children with spastic cerebral palsy. Physical Therapy 70: 65–78

Kugler PN, Turvey MT 1987 Information, natural law, and the self-assembly of rhythmic movement. Lawrence Erlbaum Associates Inc, Hillsdale, NJ

Kugler PN, Kelso JAS, Turvey MT 1980 On the concept of coordinative structures as dissipative structures: I. Theoretical lines of convergence. In: Stelmach GE, Requin J (eds) Tutorials in motor behavior, pp 3–47. North-Holland, Amsterdam

Lough S 1987 Visual control of arm movement in the stroke patient. International Journal of Rehabilitation Research 10: 113–119

Malouin F, Potvin M, Prevost J, Richards CL, Wood-Dauphinee S 1992 Use of an intensive task-oriented gait training program in a series of patients with acute cerebrovascular accidents. Physical Therapy 72: 781–793

Marteniuk RG, MacKenzie CL, Jeannerod M, Athenes S, Dugas C 1987 Constraints on human arm movement trajectories. Canadian Journal of Psychology 41: 365–378

Marteniuk RG, MacKenzie CL, Leavitt JL 1988 Representational and physical accounts of motor control and learning: Can they account for the data? In: Colley AM, Beech JR (eds) Cognition and action in skilled behaviour. North-Holland, Amsterdam

Mulder T, Geurts S 1991 The assessment of motor dysfunctions: Preliminaries to a disability-oriented approach. Human Movement Science 10: 565–574

Mulder T, Hulstyn W 1984 Sensory feedback therapy and theoretical knowledge of motor control and learning. American Journal of Physical Medicine 63: 226–244

Olney SJ, Costigan PA, Hedden DM 1987 Mechanical energy patterns in gait of cerebral palsied children with hemiplegia. Physical Therapy 67: 1348–1354

Phillips JG, Stelmach G, Teasdale N 1989 Preliminary assessment of spatio-temporal control of handwriting in Parkinsonians. In: Plamondon R, Suen CY, Simner ML (eds) Computer recognition and human production of handwriting, pp 317–331. World Scientific Publishing Co, Singapore

Phillips JG, Stelmach G, Teasdale N 1991 What can indices of handwriting quality tell us about Parkinsonian handwriting? Human Movement Science 10: 301–314

Poizner H, Mack L, Verfaellie M, Gonzalez Rothi LJ, Heilman KM 1990 Three-dimensional computergraphic analysis of apraxia. Brain 113: 85–101

Reed ES 1988 Applying the theory of action systems to the study of motor skills. In: Meijer OG, Roth K (eds) Complex movement behaviour: 'The' motor–action controversy, pp 45–86. North-Holland, Amsterdam

Rogers MW, Deming Hedman L, Pai Y-C 1993 Kinetic analysis of dynamic transitions in stance support accompanying voluntary leg flexion movements in hemiparetic adults. Archives of Physical Medicine and Rehabilitation 74: 19–25

Rozendal RH 1989 Gait analysis and ICIDH. Journal of Rehabilitation Sciences 2: 89–93

Schmidt RA 1988 Motor and action perspectives on motor control. In: Meijer OG, Roth K (eds) Complex movement behaviour: 'The' motor–action controversy, pp 3–44. North-Holland, Amsterdam

Trombly CA 1992 Deficits of reaching in subjects with left hemiparesis: A pilot study. American Journal of Occupational Therapy 46: 887–897

Turvey MT 1977 Preliminaries to a theory of action with reference to vision. In: Shaw R, Bransford J (eds) Perceiving, acting, and knowing: Toward an ecological psychology, pp 211–265. Lawrence Erlbaum Associates Inc, Hillsdale, NJ

Van der Weel FR, van der Meer B, Lee DN 1991 Effect of task on movement control in cerebral palsy: Implications for assessment and therapy. Developmental Medicine and Child Neurology 33: 419–426

van Vliet P 1993 An investigation of the task specificity of reaching: Implications for re-training. Physiotherapy Theory and Practice 9: 69–76

Woollacott MH, Shumway-Cook A 1990 Changes in posture control across the lifespan – A systems approach. Physical Therapy 70: 799–807