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Cognition and Action in Skilled Behaviour

A. M. Colley
J. R. Beech
Editors

North-Holland

COGNITION AND ACTION IN SKILLED BEHAVIOUR

Edited by

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PREFACE

In April 1987, the First International Conference on Skilled Behaviour took place at Sussex University. This conference was co-sponsored by the Cognitive Section of the British Psychological Society and by our own university department. It grew from a conviction that recent advances in different areas of skills research had not been presented and discussed in a major U.K. conference. The papers presented at the conference covered aspects of motor skills, cognitive skills, social skills and clinical skills. This volume contains chapters based upon selected papers on motor and cognitive skills.

The distribution of papers submitted to this conference by area, served to support an observation that we had previously made in surveying the skills literature; that "skills" is very often taken to be synonymous with perceptual-motor skills. Although the general applicability of a skills framework has been long acknowledged (see for example Fitts & Posner, 1967), researchers have been slow to look at performance in purely cognitive tasks such as memory and problem-solving from this viewpoint. Many skills have both motor and cognitive components. The relative importance and complexity of these varies with the skill in question. In recent years, considerable advances have been made in our understanding of movement skills. What is clear from this volume, and from many other publications, is that mainstream research into the acquisition and control of skilled movement has taken on board the terminology and major ideas from action systems theory. These have not necessarily been adopted in their strongest form, but their influence is discernible in many of the chapters here. In parallel with these developments in the movement skills area, have been recent theoretical advances in the central areas of memory and learning in cognitive psychology. These have had far-reaching implications for our understanding of a wide range of skills, from purely cognitive tasks to those which have a substantial motor component.

As might be expected from a conference with rather a general theme, the chapters in the book represent a number of different approaches to the study of skilled action. Three of the four sections of the book are collections of individual presentations and are grouped thematically. The remaining section is based upon a lively, but good-humoured, symposium on "The action systems / motor systems controversy" which was organised by Onno Meijer and Piet van Wieringen.

The chapters in the first two sections are concerned with the theoretical issues of programming and coordination, and the learning and performance of skilled movements, respectively. This latter section contains papers with some practical implications for everyday skills. Issues raised in the third section on action systems and motor systems approaches to motor control are basic to much of the research reviewed in this volume. There have been several recent debates on the role of cognitive processes in motor control, and the usefulness of the "psychomotor" approach (see, for example, the commentaries on Zanone and Hauert's (1987) arguments for a cognitive approach to motor control). This section summarises the various theoretical positions in this debate, and also contains chapters based on individual papers which present relevant empirical findings. The fourth section contains chapters on cognitive processes in skilled performance.

We gratefully acknowledge the assistance and support of the following individuals who have helped to make this volume possible. First we must thank John Whiting, who encouraged us to publish these proceedings, and who gave us help and advice throughout the preparations for the conference and for the book. His department has contributed substantially to both the conference and this book. Sue Lloyd made an excellent job of typing the camera-ready copy for this book, amid delays and minor calamities (not all book-related). Dr. K. Michielson and the staff at North-Holland have been both efficient and patient.

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CONTENTS

Cognition and Action in Skilled Behaviour
A.M. Colley and J.R. Beech (Editors)

GROUNDS FOR RECONCILIATION : SOME PRELIMINARY THOUGHTS ON COGNITION AND ACTION

Ann M. Colley and John R. Beech
University of Leicester

One of the major issues to emerge from recent perspectives on the nature of attention, memory and motor control, concerns the way in which cognitive processes interact with the motor system to produce planned coordinated action. How do intentions and strategies result in well-executed movement? Tasks vary in the amount of cognitive processing they require, and, within tasks, the stage of skill acquisition will affect the nature of the processing that is undertaken. Adams (1987) has recently pointed out that theories of action have given little consideration to how perception and action are linked, and that we have little systematic knowledge of the relationship between language and action. The amount of control that can be exerted on lower-level motor processes by higher level cognitive processes should be of central concern in any account of the acquisition of skilled movement.

This issue has been taken up by the action systems theorists. Their view, which has resulted from the influence of Bernstein (1967), and the ecological approach of Turvey, Kugler and collaborators (e.g. Kugler, Kelso, & Turvey, 1982; Turvey, 1977; Turvey & Carello, 1986; Turvey & Kugler, 1984; Turvey, Shaw, & Mace, 1978), is that the acquisition of skilled movement occurs when movement structures are constrained to behave in a manner appropriate for the attainment of a particular goal. More specifically, ensembles of motor units (muscles, joints, etc.) are constrained to act as functional units or coordinative structures, thereby reducing the degrees of freedom which apply to the control of a given task, and providing the basic organisation of movement. Reflexes, or functional configurations thereof, may provide the basis for coordinative structures (Turvey, 1977). Global constraints, or organisational invariants, specify the characteristics of different types of movements. Local constraints tune a movement to its environment and are defined by the interaction between the actor and the environment. In the initial stages, acquiring a movement skill consists of discovering the appropriate organisational invariant.

The system of global and local constraints proposed by ecological theorists carries with it the implication that control of movement is distributed at a number of levels in the nervous system and is heterarchical in nature. Hierarchical control, espoused by many early theorists (e.g. Fitts, 1964; Miller, Galanter, & Pribram, 1960), uses the notion that executive control at the highest level is responsible for a global specification of how a movement, or sequence of movements will be executed. Lower levels of the hierarchy provide more detailed specifications for the enactment of the movement. However, it is apparent from neurophysiological and anatomical evidence that the relationship between higher and lower centres is more flexible than this (see Turvey, 1977, pp.224-225 for a fuller explication of this point), and that local information about the environment and the state of the limbs may modify instructions from higher centres. Because lower level coordinative structures can function autonomously in response to the environment, higher centres need not play any role in necessary small-scale adjustments and may therefore remain in ignorance of them. This sets limits on the role of higher centres in the control of movement. Turvey (1977) argues that the Action Plan which directs movement at a high level, identifies the coordinative structures necessary for a particular movement, and how these will be functionally related in the execution of the movement. The relationship specified by the Action Plan may be modified when local information from lower centres becomes available, so that a movement can be tuned by its environment. The influence of the action systems approach is discernible in the research described in many of the chapters in this volume.

One problem for any researcher concerned with learning rather than purely performance, is how constraints are selected in the first place. Saltzman and Kelso (1983) describe the early stages of motor skill learning as being characterised by a tendency to reduce the complexity of the movement by keeping much of the body stiff. Initially constraints are applied to provide a rough approximation to the necessary movement. Practice, and therefore experience, of the reactive forces which operate when the actor makes a given movement in a given environment, allows the constraints initially applied to be selectively relaxed. Therefore the dynamics of the movement are gradually discovered. This explanation points toward examining the kinematic and biomechanical properties of movements which operate over a learning period, in order to understand the mechanisms of learning. By careful description of the changes which occur, we should be able to go some way toward a description of the manner in which the constraints are applied and tuned for a particular skill. This approach does not, however, address the problem of how constraints are initially selected when a new task is encountered. Cognitive processes play a substantial role in the initial stages of learning most movement skills. Selection of the appropriate task components is mediated by symbolic representation; by coaching, instruction or imitation. Cognitive processes must be able to specify global constraints, albeit in a rather crude manner. How they do this is, as yet, far from clear.

Early studies of skill focussed on examining changes in the way in which we attend to and process perceptual information and choose appropriate responses based on this information during skill acquisition. Action system theorists have argued against a conception of information as separate from response:

> ...ecological realism denies a dualism of information (that controls and coordinates) and dynamics (that is controlled and coordinated). Fundamentally, ecological

> realism views information as arising in the dynamics of the animal-environment system, unique and specific to those dynamics and to the system's dimensions.
> (Kugler, Kelso, & Turvey, 1982, p.48.)

In the Gibsonian tradition they proposed a direct linkage between perceptual cues and the actions they "afford". In learning skilled movement, this linkage must be established. Although a direct triggering of action from perceptual cues such as tau (time to contact with an approaching surface; Lee, 1980) may provide a plausible explanation of performance of movements such as locomotion, stair-climbing and ball catching (see also Turvey & Carello, this volume), in many human skills decisional processes are necessary at all grades of performance from novice to expert. Of course, as Turvey and Carello point out, the performer must be able to perceive that the environment permits a particular action, and this argues for the existence of what Turvey and Carello describe as "smart perceptual instruments".

Epstein (1986) distinguishes "realist" (action systems) from "standard" (motor systems) views of perception and action, and does not feel that the two are incompatible. The standard viewpoint emphasises central programming of movement and error correction during execution using feedback. Epstein argues that hybrids of the two approaches provide good options to either extreme position. A rather general "hybrid" view of the role of cognition in motor control, is that there is a number of skills in which the direct linkage of perception with action underlies performance. Further processing is involved when the task or stage of learning requires it. Much of the literature on the acquisition of "perceptual-motor" skills in the 1950s and 1960s was based on tasks with an obvious cognitive component. It is therefore not surprising that the models produced at this time represented the organisation of the components of skill as a hierarchy, with a decision-making executive at the top, which structured the components of a task required to achieve a particular goal. Further down the hierarchy, smaller and smaller components, or subroutines, contained the detail of performance. At the bottom of the hierarchy were well-learned "habits" or reflexes. The model presented by Glencross (1978) illustrates this form of theorising. He distinguished four levels of "plans" which represent the cognitive structure of skills. At the top, or Directive Plan Level, the goal and desired outcome of the activity is represented. The second level contains General Plans which deal with strategic factors, and the rules and limitations of the task. The third level contains Motor Plans for spatially and temporally organised movement patterns, and at the lowest level Motor Programmes which are "response units of action". Responses are constructed from basic units into programmes and response patterns under the guidance of the directive and strategic plans, which act in an executive manner. One major difference between models such as that of Glencross, and the view-point advanced by Turvey and colleagues, concerns the amount of control exerted by "executive" levels and the interpretation of a response unit of action, which in the ecological view would be an autonomous coordinative structure. Neither viewpoint tells us very much about strategic factors or intentions in performance, although both of these are represented as plan levels by Glencross.

A distinction which can be drawn in Glencross's model, and which is common to many similar descriptions of skilled behaviour, differentiates between higher levels of control which allow goals and intentions to access the control mechanisms necessary to accomplish them, and lower levels of control which tune the performance of skill to its environment. The ecological theorists have avoided the issue of intentionality:

> ... (We respectfully ignore the problem of how an intention is determined and in addition we give due recognition to the likelihood that some of the structures responsible for determining an intention may also be responsible for its translation into an action plan and for the plan's subsequent differentiation.) Therefore, an intention is an 'event' for the action system in the way that, say, a scene is an event for the visual, perceptual system.
>
> (Turvey, 1977, p.222.)

This suggests that even the ecological theorists would support some distinction between higher level cognitive processes and those processes directly responsible for movement control. Other theorists have drawn a similar distinction more directly. Mackay (1983) distinguishes between the conceptual system which contains "cognitive units for controlling movements" and the muscle movement system which sets parameters for the execution of the task. Roy (1983) in his consideration of apraxic syndromes makes a similar distinction.

There does seem to be some utility in distinguishing between cognitive and motor processes. However, although we can justify such a distinction, it is important to give some consideration to how the cognitive system, which we assume uses representations based upon propositions or imagery, passes control to motor centres, which have to issue commands to specify the activity necessary for the muscular forces which constitute action.

Cognitive processes in action

Annett (1985) points to the possible role of imagery as the "bridge" between action and language. Words can evoke images, which in turn can summon actions. Part of the support for this notion comes from the effectiveness of using descriptions which produce imagery to convey information about posture in the early stages of coaching a skill. Annett gives the example of a squash coach who instructs novices to receive service by adopting the stance of Red Indians waving tomahawks. Further support comes from the reported spontaneous usage of imagery by subjects attempting to describe how they perform certain actions, for example, tying a bow. These examples certainly suggest that imagery has an important role in accessing action routines.

Where in the cognitive system is it necessary to place this bridge? Our access to the cognitive system is mediated symbolically, but the mode of communication of the cognitive system and the motor system is the same. The locus of the bridge must be at peripheral stages of access to the cognitive system, where we are encoding material, rehearsing it in working memory or retrieving it from storage.