CHAPTER 15

Action-Theory Approach to Applied Sport Psychology

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A typical track and field sports event reveals a great deal of diversity. While a pole-vaulter is getting ready for the next vault, the starting pistol goes off and a group of track athletes break explosively into a 100 m sprint. A coach is helping an athlete to prepare herself mentally for a decisive high jump, while another group of athletes is relaxing on a mat at the edge of the stadium. During this time, spectators watch and applaud when appropriate.

Such a diversity of behaviors also suggests diversity in task-related and situation-related components. For example, the behavior of the 100 m sprinters seems to rely on simple reaction time after the pistol shot. The behavior of the spectators seems to rely on the performance of the athletes. The relaxing group of athletes is engaged in regulating physiological or psychological processes, and the coach is busy in consultation and provision of instructions to the athletes.

However, the events observed in the stadium rely, among other things, on the experiences, specific viewpoints, and conceptual framework of the sport psychologist. The action-theory approach formulates a fundamental concept of actions in sport and thereby provides a consistent and plausible basis for explaining the diversity of phenomena in sport practice. The theoretical foundation and empirical evidence of the fundamental aspects of actions in sport should promote and support the practical work of sport psychologists.

NEED FOR A COMPREHENSIVE THEORY

There are several reasons for formulating an action-theory approach:

• *Previous basic concepts of human behavior are either not formulated explicitly or are inadequate.* Numerous authors have criticized the theoretical and terminological "fragmentation" of psychology (see Nitsch, 2004). A variety of theoretical approaches often tackle only single and isolated functions and components of human action, such as emotions, motivations, or cognitions, without relating them to broader goals, plans, or action processes. This state of affairs was criticized by Vygotsky (1927) and later by Holzkamp (1972) and Rubinstein (1984). A further notable criticism was expressed by Prinz (1997, 1998). He outlined how psychology often follows a line of thought established by Descartes (1664) that views human behavior only in terms of reactions. Many psychologists interpret experiments purely as stimulus-reaction constellations; other professionals in sport view the 100 m start, for example, only in terms of the athlete's reaction to the pistol shot. Analyzing the construction and control of actions offers a number of advantages over the stimulus-reaction sequence. A functional approach to actions can also integrate, for example, the individual goals and anticipations that are so crucially important not only in psychological experiments but also in the practice of sport.

• *Applied psychology has an inadequate theoretical foundation.* The pure-research-oriented psychological disciplines (such as general psychology and developmental psychology) rely on different theoretical perspectives. One outcome of this has been a lack of any binding or fundamental theoretical approach in the applied disciplines (industrial psychology, clinical psychology, sport psychology, etc.). As a consequence, most sport psychologists cultivate their own theoretical basis for their practical work. Frequently, they are not aware of this theoretical basis, refraining from communication and thus avoiding any possibility of change. However, we believe that a good theory is of enormous value in practical work and that it is highly advantageous for sports psychologists working in the field to have a functional understanding of sport actions at their disposal.

ESSENTIAL ASSUMPTIONS FOR AN ACTION-THEORY APPROACH

The action-theory approach has a number of different historical roots. These include Miller, Galanter, and Pribram's (1960) book *Plans and the Structure of Behavior* that broke away from behaviorist concepts and formulated preliminary ideas on the functional construction of action. Further roots are to be found in German (Ach, 1905; Lewin, 1926) and Russian psychology (Luria, 1978; Rubinstein, 1964; Vygotsky, 1978). In the applied disciplines, the action-theory approach has been formulated most elaborately for industrial psychology (e.g., Hacker, 1998) and sport psychology (Hackfort, 1986, 2000; Hackfort & Munzert, 2005; Hackfort, Munzert, & Seiler, 2000; Nitsch, 1975, 1985, 2004; Schack, 1997, 2000).* We focus on applied sport psychology, and we start by enumerating the essential assumptions underlying an action-theory approach in this field:

Sport action is an intentional event. This means that the various sequences or elements of a behavior that can be observed externally are carried out to attain a specific action goal. Hence, sport activities are always performed relative to a goal and are directed toward this goal. This gives all psychological processes and structures (emotions, representations, etc.) an action-regulating function.

A fundamental action situation in sport consists of the following components: person, task, and environment (Nitsch, 1982, 1985, 2000, 2004; Nitsch & Hackfort, 1981; see also, Newell, 1986). With these components, every sport situation can be accounted for in more detail. Sport performance depends on the current physical and mental condition of the athlete (person), on the situational demand or the type of sport (task), and on the conditions under which the task must be carried out (environment). This may vary strongly between, for example, training and competition (environment). From this perspective, actions are organized intentionally in line with a person's subjective interpretation of a given person-task-environment constellation (action situation). However, this does not mean that actions are completely conscious.

The assumption of intentionality has some important implications. First, it implies some kind of internal representation of the person-environment-task constellation. Second, it requires the formulation of a functional understanding of how intentions (ideas) find their path from the center to the periphery (in the action regulation system, the brain/cognitive processes are regarded as the center and the muscles/body movements as the periphery). In the action-theory perspective, self-instructions forge an important link between intentions and external behavior.

• *Sport actions are embedded within various systems. A* systems-oriented perspective is useful for sport psychologists working in the field when they must analyze problems or structures that they are confronting. A potential structuring of the relevant systems for an action is given in Figure 15.1.

Athletes are embedded within social systems. These may be friends or family, as well as the social situation in a competition. However, human beings also have to be viewed as a physical system, particularly when they are engaged in movement actions. Movement effects are always

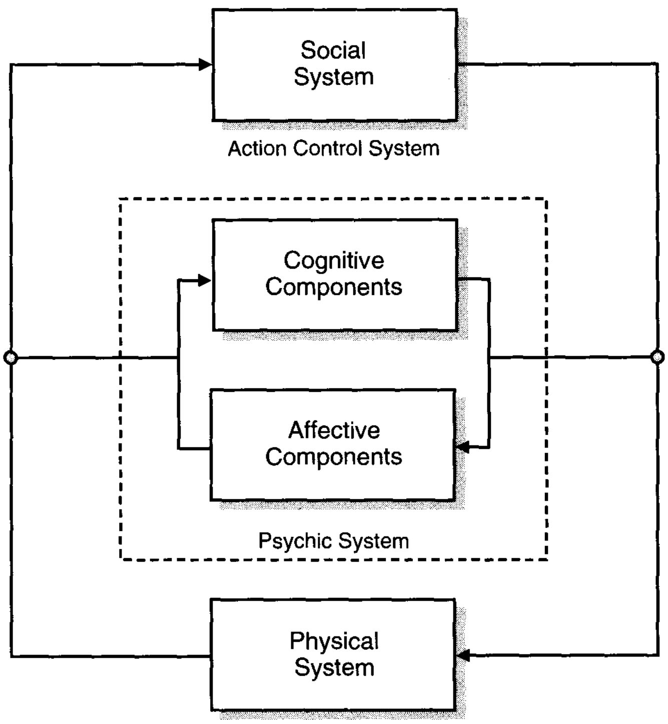
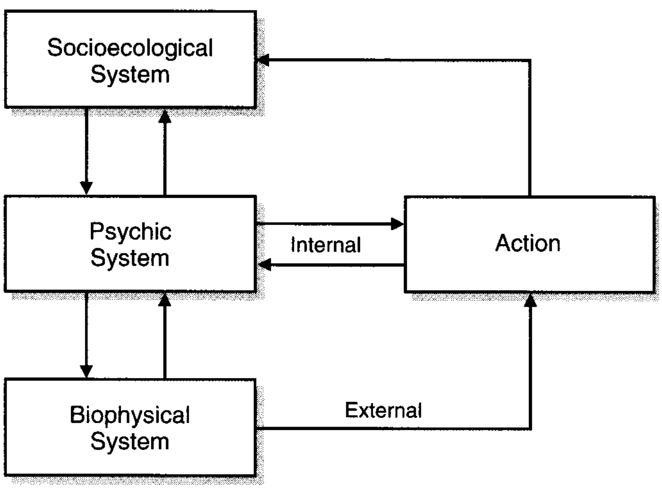


Figure 15.1 Action control from a system-theory perspective

*There have also been interesting developments in the field of E movement science, particularly motor control. For example, Jeannerod (1997, 2004) has formulated a neuropsychological concept of action planning. Other authors have formulated an ideomotor theory of action control (Hoffmann, Stoecker, & Kunde, 2004; Prinz, 1997), and there are now some studies addressing "the construction of action" on an experimental basis (see the two special issues by Schack & Tenenbaum, 2004a, physical effects as well, such as vaulting over a bar or long jumping. Major parts of the competitive conditions of a sport are defined within this physical system (e.g., wind, lighting conditions, water temperature). Moreover, the psychological system of the athlete should be taken into account. This includes, for example, cognitive or affective components. All these systems are dynamic. Hence, they initially possess a function and are composed of various elements. Another crucial aspect is that they possess a history. These systems have an environment and, as a result, greater or smaller degrees of freedom. The action-control system may be located, for example, between the social and the psychological system. It depends very strongly on the physical system and also tries to achieve an effect within this system. However, in principle, it is possible to exert only a minimal influence on the physical system. These system characteristics are important for the sport psychologist in the field who aims at modifying the athlete's action or behavior. For example, it is better to avoid considering the athlete's performance or social problems in isolation and to analyze these systematically.

The systems that influence an athlete's individual performance are tied very strongly to his or her action goals. This is illustrated in Figure 15.2, showing that the athlete should primarily be conceived as a biopsychosocial unit. As a result, physiological processes (such as regeneration or the healing of injuries) also depend very strongly on psychological and social framing conditions. For the psychological system, in turn, the biological and social framing conditions are crucial. Nonetheless, the psychological system is capable of altering these framing conditions

Figure 15.2 Interrelation of systems with respect to actions.



through its own action, giving this system some degree of freedom. The task of the sport psychologist in the field is to help the athlete to exploit these degrees of freedom and attain optimal performance. This may mean, for example, learning how to handle the social demands of a competition (spectators, mass media, etc.). However, this also indicates that physiological variables (tiredness, stress, etc.) do not impact directly (in a deterministic way) on an athlete's performance but are mediated by the psychological system.

• *Every sport action can be broken down into its structure and process.* The structure of an action is discussed later in the chapter as the construction of action. We shall look at the process of the action here. Sport actions can be broken down into various phases (Nitsch, 2004). In the first phase, the action *anticipation* phase, the outcome of the action and its concrete course are anticipated. In the second phase, the *realization* phase, the planned action is implemented and its performance is adapted to fit given conditions. In the *interpretation* phase, the outcome of the action is compared with the action goal and expectations. This is where the course of the action and its effectiveness are interpreted.

Taking such an approach to the action process has benefits for psychological sport training. It becomes possible to relate training procedures to the single steps of the process. Whereas psyching up and psyching down techniques are typical for tuning, attention control training is essential to improve the processing of movement actions in the realization phase. Goal setting is a typical strategy to improve anticipation (planning and calculation), and attribution strategies or techniques to modify attributions are characteristic for psychological interventions to improve the interpretation of actions and to encourage motivation and volition.

A FUNCTIONAL PERSPECTIVE ON ACTION ORGANIZATION

The task-person-environment constellation presented in Figure 15.3 is fundamental for the understanding of the construction of actions. Furthermore, an analysis of the conditional framework of actions is essential for the development of applied perspectives (Figure 15.2). We first analyze the system of actions in more depth. According to the action-theory approach, we integrate the latest results of research gained in the fields of psychology and sport science to derive an applied perspective.

To attain such a perspective and take a first step toward improving knowledge and methods, we reflect on the functional organization of actions. Different approaches con-

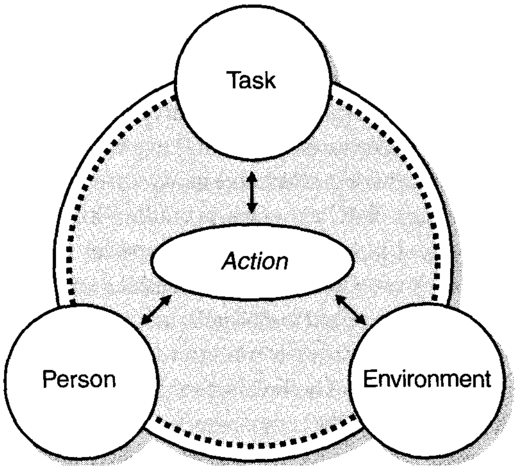


Figure15.3 Action situation as a person-environment-task constellation.

tribute to an action-theory perspective. Current findings from neurophysiology, biocybernetics, and psychology emphasize the relevance of cognitive-perceptual effects for the organization and control of actions (Schack & Tenenbaum, 2004a, 2004b). These new approaches have much in common with an action-theory perspective. They emphasize the goal-directedness of actions and the crucial role of mental representations for action control. Hence, they are characterized by the common idea that voluntary movements might basically be planned, performed, and stored in memory through representations of anticipated effects. New and interesting perspectives have emerged on how such perceptual-cognitive structures develop in action control. These include the ideomotor approach (see Knuf, Aschersleben, & Prinz, 2001; Koch, Keller, & Prinz, 2004), the theory of event coding (see Hommel, Miisseler, Aschersleben, & Prinz, 2001), and the anticipative behavioral control approach (see Hoffmann, 1993; Hoffmann, Stoecker, & Kunde, 2004). Various experiments have shown that sensory information and effect representations play a major role in the mental control of movements. For example, Kunde (2003, 2004) has demonstrated that presenting optical or acoustic response-affording targets can speed up motor responses. Through their shared basic idea that voluntary movements may be planned, performed, and stored in memory by representations of anticipated effects, these theories differ from theories that conceive of motor programs as a prestructured set of muscle-oriented commands and assume that movements are initiated without regard to sensory information (see Schmidt & Lee, 1999). However, they also differ specifically from the dynamic system approach (Kelso, 1995). For example, Mechsner, Kerzel, Knoblich, and Prinz (2001) have shown that the spontaneous tendency toward symmetry that sets in with bimanual finger movements is not due to the coactivation of homologous muscles (see Kelso, 1984), but to a spatiotemporal symmetry tendency based on perceptual information. The authors view this result as support for the assumption that human movements are organized on the basis of sensory effect representations.

When integrating such topical results into an action-theory approach to applied sport psychology, it is necessary to consider the functional components of action. We next define the building blocks and levels of the organization of action more closely.

In his now classic work *O postrojenii dvizenij* (On the construction of movement), Bernstein (1947) presented the most comprehensive compilation of descriptive and experimental data on the functional mediation of the building blocks of the action system available at that time. His detailed model of the interplay among, for example, movement goals, motor representations, and perceptual feedback is composed of several interdependent levels in a hierarchy headed by an object-related action organization level. He even claimed that there should be a superordinate cognitive level of symbolic or conceptual organization for complex movements, but he did not work out this idea in detail.

From an evolutionary perspective, conscious mental functions can be assumed to emerge from more elementary functions. As the discussion on the evolution of the human action system (e.g., Bernstein, 1996; Schack, 2004b; Vygotsky, 1978) has shown, symbols (as specific cognitive tools) convey higher, mentally controlled functions. Hence, whereas elementary functions (e.g., reflexes) are influenced directly by stimulus constellations, mental control functions are guided intentionally; they are regulated by the self. For example, it is not possible for a mentally controlled action to emerge from the grasp reflex in humans. In fact, this reflex has to be inhibited actively before verbal or other cognitive means can be applied and a goaldirected action can be formed. Should children fail at this point to develop any inhibitory activity, they cannot manipulate objects at all. All they will do is grasp. The same applies on an ontogenetically more advanced level to associations (between stimuli and action schemes) that were found appropriate at one time in the past but have now become (automated and) purposeless. This points to the *vertical dimension (hierarchical organization) of cognitive control.* As the organization of the organism-environment interaction becomes increasingly effective, various levels of functional organization also seem to have been formed.

Since Bernstein's (1947) approach to the construction of action, there have been several formulations of the idea that movement control is constructed hierarchically. One set of studies has focused on a hierarchy of different levels of representation (see, e.g., Keele, 1986; Perrig & Hofer, 1989; Saltzman, 1979). Other studies, in contrast, have focused more strongly on hierarchic execution regulation (e.g., Greene, 1972; Hacker, 1998; Keele, Cohen, & Ivry, 1990; Rosenbaum, Hindorff, & Munro, 1987). The present model bases the functional construction of actions (Schack, 2002, 2004a) on a reciprocal assignment of performance-oriented regulation levels and representational levels (see Table 15.1). These levels differ according to their central tasks on the regulation and representation levels, and are each assumed to be functionally autonomous.

The function of the mental control level (Level IV) has already been sketched for voluntary movement regulation and the coding or anticipated outcome of movement. The level of mental representations (Level III) predominantly forms a cognitive benchmark for Level IV. It is organized conceptually, and is responsible for translating the anticipated action outcome into an appropriate movement program that will lead to the desired outcome. Because an action is "no chain of details, but a structure subdivided into details" (Bernstein, 1988, p. 27, translated), action organization has to possess a working model of this structure. The abilities to use such targets and representations have been acquired stepwise during evolution (Schack, 2004b), and the current level of human development can draw on hierarchically organized representations of either states in the environment, objects, or goal-directed movements.

So-called basic action concepts (BACs) have been identified as major representation units for complex movements (Schack, 2002) that link together their functional and sensory features. The functional features are derived from movement goals linking BACs to Level IV. However, BACs also integrate sensory features of submovements through, for example, chunking. This links them to Level II, as they also refer to the perceptual effects of the movement. Finally, the connection between BACs and sensory effect representations permits the intentional manipulation of the cognitive framing conditions of sensorimotor coordination. These mental representations (BACs) are the subject of the next section and the experimental analyses reported subsequently. Although BACs contain a kind of knowledge that relates directly to performance, the model also reveals clearly that they are functionally embedded in further levels and components of action organization.

This makes it necessary to sketch the functioning of the lower levels (I and II). The level of sensorimotor control (I) is linked directly to the environment. In contrast to the level of mental control (IV), which, as just explained, is induced intentionally, this level is induced perceptually. It is built on functional units composed of perceptual effect representations, afferent feedback, and effectors. The essential invariant (set value) of such functional units is the representation of the movement effect within the framework of the action. The system is broadly autonomous, and automatisms will emerge when this level possesses sufficient correction mechanisms to ensure the stable attainment of the intended effect.

The need for a level of sensorimotor representation (Level II) is obvious in this context. It can be assumed that this is where, among others, the modality-specific information representing the effect of the particular movement is stored. The relevant modalities change as a function of the level of expertise in the learning process and as a function of the concrete task. Kinesthetic representations are also found on this level. It is clear that eye-to-hand coordination has emerged during the course of evolution. In prior stages of evolution, kinesthetic feedback was predominantly responsible for controlling the extremities. However, grasping movements have now become associated with kinesthetic, tactile, optical, and, in part, auditory feedback (e.g., when cracking a nut). This requires a representation of perceptual patterns of exteroceptive and proprioceptive effects that result from the structure of the particular movement and refer back to the goal of the action.

Table 15.1 Levels of Action Organization

Code	Level	Main Function	Subfunction	Means
IV	Mental control	Regulation	Volitional initiation control strategies	Symbols, strategies
III	Mental representation	Representation	Effect-oriented adjustment	Basic action concepts
II	Sensorimotor representation	Representation	Spatial-temporal adjustment	Perceptual effect representations
I	Sensorimotor control	Regulation	Automatization	Functional systems, basic reflexes

Empirical findings on these two lower levels come from studies on the physiology of movement. Anochin (1967, 1978) has identified an *action acceptor* as an important functional component in these goal-directed movements. It translates the intended action outcome into a sensory (perceptive) model of the action effects, thus providing criteria to guide the system's comparison and control processes. The outcome of this process is knowing how, for example, a product feels at the end of the work process, what it looks like, and how to use it. This component simultaneously draws on the criteria that have been generated to evaluate the action steps performed. Its existence is also confirmed by neuropsychological research. Patients who are unable to draw on their action acceptor (e.g., due to frontal lobe brain damage) are still able to formulate an intention and even control the enactment of this task by third persons (recognizing any errors they make). However, they no longer possess control over their own actions or are able to evaluate errors in their own action performance (see Luria, 1992; Luria, Pribram, & Chomskaja, 1964).

What is interesting for complex movements in sport is that routines, such as preperformance routines in golf (Whitmarsh & Schack, 2004), emerge particularly in the interaction between the two lower levels. From a certain stage of learning onward, these levels are broadly autonomous. However, during the learning process, they become embedded within the action, thus entering into a functional interaction with Levels III and IV (Schack, 2002). Increasing automatization is accompanied by increasingly adequate correction mechanisms between Levels I and II, and so-called tacit knowledge (see, e.g., Sternberg, 1995) emerges. The routines that develop here are direct components of high-level performance. According to the present model, the emergence and stabilization of such routines is supported not only by sensorimotor representations but also by mental representations. This means that tacit knowledge also builds on knowledge structures that are localized on the level of mental representations. This is what makes it possible to also assess this knowledge base of performance experimentally.

THE CONNECTION BETWEEN ACTION THEORY AND APPLIED FIELDS

When a sport psychologist transfers theoretical knowledge to applied work, it is necessary to think about the interaction of theory, technology, and practice. For the actions performed by sport psychologists or therapists (their technology), theory represents a framework that usually relates to a practical problem. Such ideas can be found in Barlow, Hayes, and Nelson's (1984) science-practitioner model and in the self-management therapy approach proposed by Kanfer, Reinecker, and Schmelzer (1991). The crucial aspect is that a theory is primarily used in connection with practical problems and that its value is then derived from evaluating its practical impact. However, practical steps (training, intervention techniques) have to be attached to theory. In this respect, nothing would be more practical than a good theory.

When taking an action-theory approach, the theoretical concept of the construction of action (see Figure 15.4) is fundamental for both the development of suitable diagnosis procedures and the selection of appropriate training methods. It becomes possible to define relevant systems of action more precisely. Problems, which may, for instance, be located in the areas of emotion regulation or motivation, result from deficits in mental control. They are allocated to the level of mental control. Psychological training procedures, which intervene at this level, aim to improve basic regulation. This applies particularly for psychological training procedures targeting attention control, optimization of self-talk, stress and anxiety control, and so forth (see Figure 15.5). In contrast, the structure of a movement-and therefore its optimal technical execution-is largely determined by the level of mental representations. Consequently, training procedures designed to optimize process regulation ought to be allocated on the level of mental representations.

In applied work, it is exceptionally important to bear in mind that such different systems play a part in an athlete's performance. A frequently observed practical problem is that athletes are able to perform a certain movement optimally in

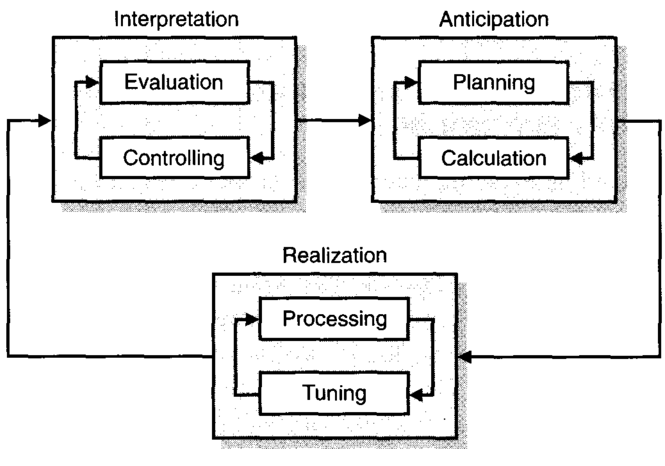


Figure 15.4 Process components of an action.

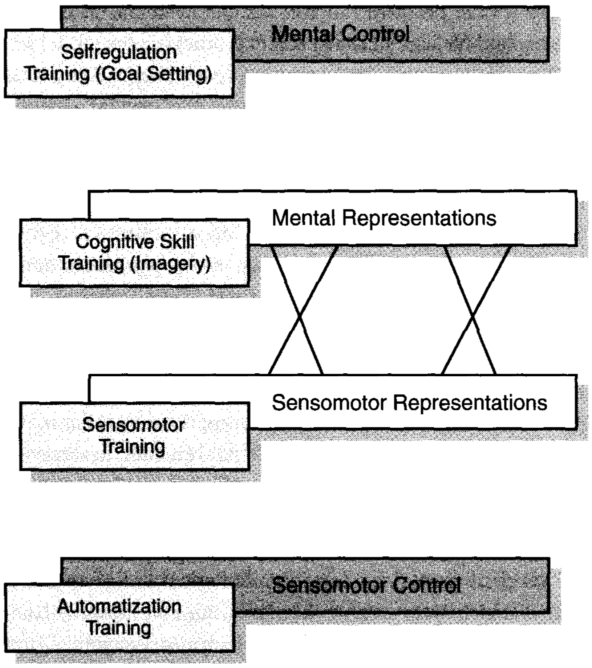


Figure 15.5 Levels of action regulation and psychological training methods.

practice but fail to do so in competitive settings. In such a case, the problem is likely to be rooted in deficits of mental control. The movement structure is accessible under less stressful circumstances (practice) and appears to be optimally represented in the athlete's memory. We have developed specific methods for a reliable diagnosis of how a movement is represented, which enables athletes to control the goal-directedness of psychological training. A method for measuring mental representation of movements is illustrated in the following section.

ACTION-ORIENTED METHODS IN APPLIED SPORT PSYCHOLOGY

According to action theory, actions take place in a person-task-environment relation. Thus, the relevant knowledge is quite specific. An athlete's mental representations relate to the action or movement-related problems he or she has to solve within the framework of voluntary acts. As a consequence, if sport psychologists wish to work from evidence-based methods, they must know the structure of the respective movement. This approach has been documented in several contributions (Schack, 2002, 2004a, 2004b; Schack & Mechsner, in press). To introduce our method for measuring mental representation, we have chosen a special action, the tennis serve, because it seems well suited to an investigation of potential conceptual representational structures in different levels of expertise. In the tennis serve, many degrees of freedom in the musculoskeletal system have to be controlled, and performance quality is influenced considerably by training and expertise. On the other hand, it is a finite, recognizable, and thereby flexible action pattern whose overall structure is well defined by biomechanical demands (Schack & Mechsner, in press).

We start by characterizing the task-adequate functional organization of the tennis serve and formulating a plausible and workable set of basic action concepts in collaboration with nonplayers, athletes of different levels, and coaches. A tennis serve consists of three distinct phases; each fulfills distinct functional and biomechanical demands. In a preactivation phase, body and ball are brought into position, and tension energy is provided to prepare for the strike. The following BACs are identified: (a) ball throw, (b) forward movement of the pelvis, (c) bending the knees, and (d) bending the elbow. In the following strike phase, energy is conveyed to the ball. Here, the following BACs are identified: (e) frontal upper body rotation, (f) racket acceleration, (g) whole-body stretch motion, and (h) hitting point. In the final swing phase, the balance is maintained and the racket movement is decelerated after the strike. The following BACs are identified: (i) wrist flap, (j) forward bending of the body, and (k) racket follow-through.

Because the usual rating and sorting methods do not permit a psychometric analysis of the representational structure, we developed a special method for measuring mental representation structures (Lander & Lange, 1996; Schack & Schack, 2005). It has now been modified for the analysis of action representation (structural dimensional analysismotoric, or SDA-M; Schack, 2002). SDA-M consists of four steps. First, a special hierarchical split procedure involving a multiple sorting task provides a distance scaling between the BACs of a suitably predetermined set. Second, a hierarchical cluster analysis is used to transform the set of BACs into a hierarchical structure. Third, a factor analysis is applied to reveal the dimensions in this structured set of BACs. Fourth, the cluster solutions are tested for invariance within and between groups.

We provide an example. We examined three groups of tennis players: The expert group consisted of 11 males (mean age: 24 ± 3.7 years) who were players in upper German leagues and ranked between places 15 and 500 in the German men's rankings. The low-level group consisted of 11 males (mean age: 26 ± 4.8 years) who were players in lower German leagues (district leagues) and not listed in the German men's rankings. A nonplayer group consisted of 11 males (mean age: 24 ± 6.7 years) who had virtually no experience with the game (maximum: 5 hours) and had never taken any tennis lessons.

We submitted the BACs specified earlier to a hierarchical cluster analysis, with the distances based on subjective distance judgments of all combinations of pairs of BACs. In preparation, participants were familiarized with the BACs by looking at pictures with a verbal BAC name as a printed heading. These pictures were positioned in front of each participant throughout the experiment. To determine subjective distances between the BACs, the participants performed the following split procedure as the first step in the SDA-M: On a computer screen, one selected BAC was presented constantly as an anchoring unit in red writing. The rest of the BACs were presented in yellow writing as a randomly ordered list. The participant judged whether each of these additional yellow-colored BACs was "functional related" (associated) to the red anchor BAC "while performing the movement" or not. This produced two subsets that were submitted to the same procedure repeatedly until the referee decided to do no further splits. As every BAC was used as an anchoring unit, this procedure resulted in 11 decision trees per participant. In the second step of the SDA-M, the individual partitioning was determined with a hierarchical cluster analysis. In the third step, the dimensioning of the cluster solutions was performed using a factor analysis applied to a specific cluster-oriented rotation process. This resulted in a factor matrix classified by clusters. Finally, in the fourth step of the SDA-M, a within- and between-group comparison was used to test for significant differences between cluster solutions using an invariance measure. Alpha was set at 5% in all significance tests.

Figure 15.6 presents dendrograms for the subjective distances of BACs based on the hierarchical cluster analysis of the means of experts and nonplayers. Experts (Figure 15.6a) showed a cognitive structure close to the functional structure of the tennis serve. The three functional phases (i.e., preactivation, strike, and final swing) could be identified as distinct tree-like structured clusters in the dendrograms. Experts seemed to group the BACs in their memory according to generic terms that conformed to the solution of special movement problems. An invariance analysis (step 4 of SDA-M) confirmed this interpretation. There was no significant difference between the cognitive BAC framework in experts and the biomechanical demand structure of the movement (?, = .70; X_{crit} = .68). Results were rather different in nonplayers (Figure 15.6b): BAC clusterings did not reflect the functionally and biomechanically necessary phases so well. Basic action concepts were less clearly grouped, with no close neighborhoods, and the partial clusters usually failed to attain significance. The difference between the cognitive BAC framework and the functionally demanded structure of the action even attained significance in nonplayers (2, = .31; X_{crit} = .68).

The individual clusterings of BACs (data not shown here) were rather similar in experts, with an invariance analysis revealing no significant differences. Significantly distinct subclusters could also be seen in individual lowlevel players, but these were not as functionally well structured. Although the functionally and biomechanically

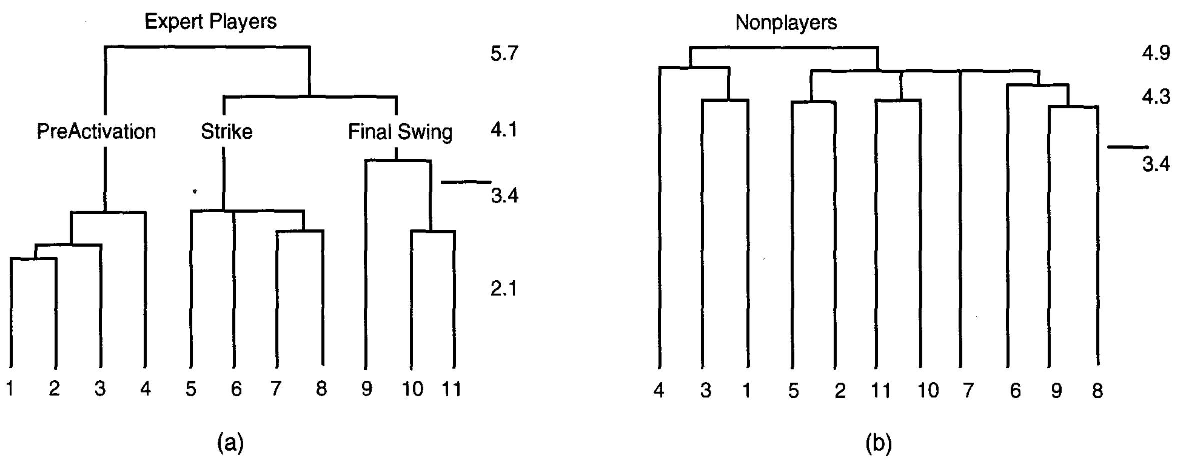


Figure 15.6 Dendrograms for two chosen expertise groups (experts and nonplayers) based on the hierarchical cluster analysis of basic action concepts (BACs) in the tennis serve. The horizontally aligned numbers denote the BACs (for the code, see text); the vertical numbers are the Euclidean distances. For every group, it holds $n = 11$; $p = .05$; $d_{crit} = 3.46$.

required phases could be discerned regularly, they were not matched so well and consistently. There were rather arbitrary associations based on surface or unfathomable criteria that often varied from person to person. As a result, interindividual differences were significant. In nonplayers, significantly distinct subclusters were generally rare and arbitrary. The structure of the clustering trees varied greatly between persons and revealed no clear grouping principles. Such experimental measurement of structures in long-term memory constitutes an essential condition for applied work. Coaches have to decide whether the athlete's memory structure corresponds to the actual movement structure. Such measurement enables them to identify problems on precisely defined levels of action. Ultimately, such information will make a substantial contribution to a coach's understanding of how to communicate with his or her athletes and how to instruct them specifically. As our further illustrations show, measuring movement representation is also a vital precondition for technical preparation, imagery training, and consulting.

APPLIED FIELDS OF SPORT PSYCHOLOGY: PSYCHOLOGICAL COMPONENTS OF TECHNICAL PREPARATION

The SDA-M method is highly applicable in the area of technical preparation (see Schack & Bar-Eli, in press). Professional windsurfing provides a good example here. Until 1986, the possibility of performing an "end over" (see Figure 15.7) was only speculated on. Nobody knew for certain how the impulse for forward rotation might be generated out of an ongoing forward motion. In 1985, Cantagalli became the first to perform a forward rotation (which he titled "Cheese Roll") in an international competition. This led to a boom of experimentation with highly complex movement actions. Mark Angulo turned this sideways rotation into the spectacular front loop (end over) with the characteristic rotation over the mast top (see Figure 15.7).

The front loop represents a mixture of a rotation around the horizontal axis and a rotation around the longitudinal axis. This movement is a technical challenge for both excellent hobby windsurfers and competitive professionals, because even many highly skilled windsurfers are unable to perform jumps involving forward rotations. Their performance requires mastery of the following subproblems of the movement task:

- The need to execute a sufficiently high jump from the water surface (optimally 5 to 8 m, yet at least as high as the mast; energizing problem).
- Introduction of the rotation at the peak of the jump. The impulse starts at the sail's pressure point, which, after takeoff from the water surface, is located above the center of the complete system. This makes it necessary to

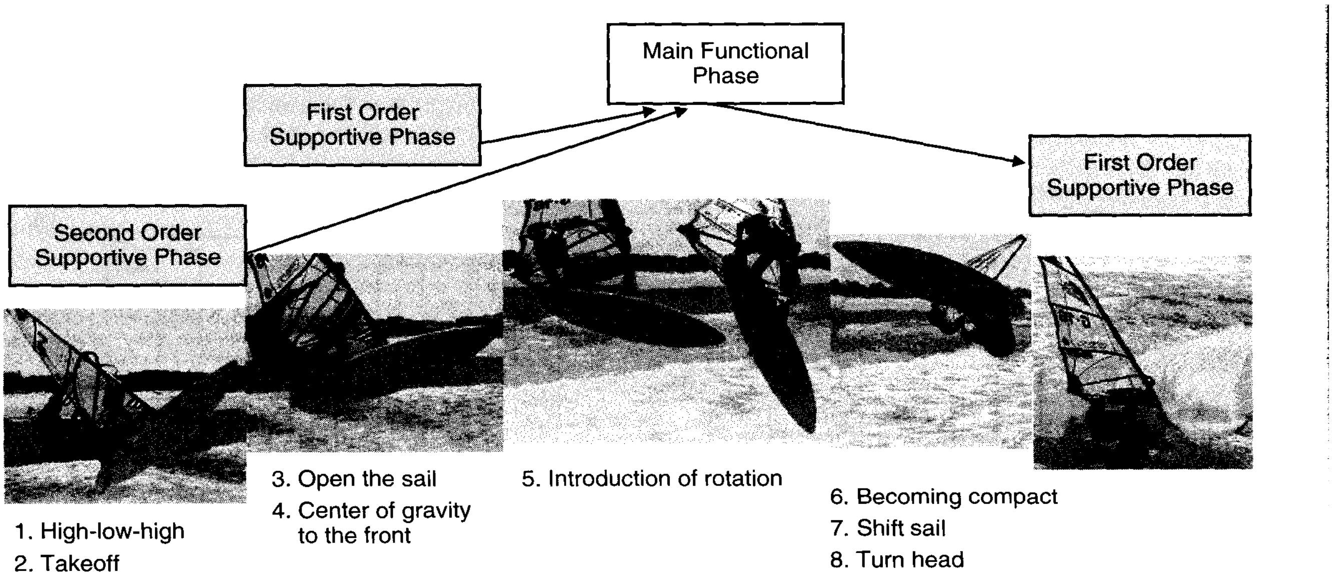


Figure 15.7 Movement phases of the front loop in windsurfing. The task-related BACs are allocated to the respective phases. In the takeoff phase, the front loop can hardly be distinguished from a regular jump. The surfer waits until the angular point of the slope angle, and then abruptly pushes the sail's pressure point forward down. Robby Nash, a surf legend, called this time lag before the introduction of the front loop the "moment of shock for the spectator." *Source:* "Loopernein," by W. Smidt, 1995, *Surf* (11/12), 61–63. Reprinted with permission.

overcome an enormous mass moment of inertia (impulse-introduction problem).

- Stabilization of the windsurfing-board system during the forward rotation (stabilization problem).
- Solution of numerous orientation problems resulting from the rotation during the whole movement. For example, a permanent orientation regarding the situation in space is necessary for initiation, stabilization, and completion of the rotational movement. The water, the sail system, and the horizon represent benchmarks in this context (orientation problem).

Basic action concepts were ascertained for the functional phases, making substantial contributions to the solution of the movement tasks and the connected movement problems. To permit an allocation to the biomechanically (functionally) determined movement phases, these BACs are already entered in Figure 15.7. The concepts relevant for the movement were gathered in a process involving several stages. First, a group of expert *(n = 8)* and novice *(n = 7)* athletes gave spontaneous descriptions of the movement (front loop in windsurfing). Subsequently, they were interviewed individually regarding the BACs from their point of view. This revealed that BACs were not just labeled verbally, but could also be demonstrated as a specific movement pattern. Following an active execution of the movement, the former results were complemented or corrected through video-based self-confrontation. Later, these findings were also controlled with allocation experiments (Schack, 2002).

The acquired BACs for the frontal loop are:

1. High-low-high
2. Takeoff
3. Opening the sail
4. Moving center of gravity to the front
5. Introduction of rotation
6. Becoming compact
7. Shifting the sail 8.

Turning the head

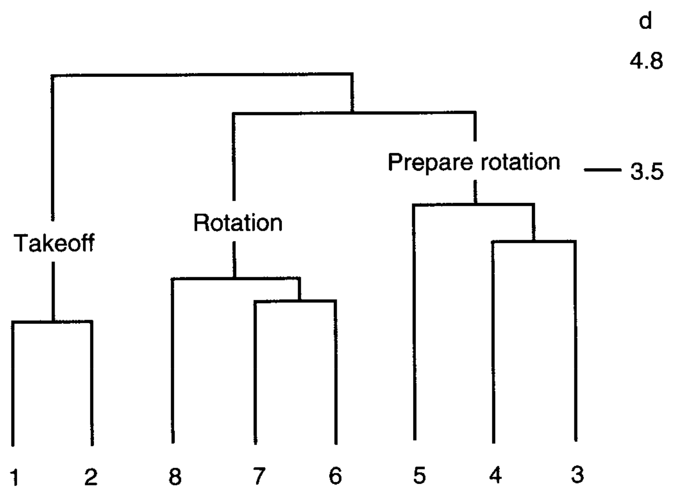
A total of 40 experts and novices participated in a special study to develop new forms of technical preparation. The 20 experts (all male) had a mean age of 28.8 years and had been engaged in windsurfing for an average of 15.8 years (performing front loops for an average of 9.4 years). This group consisted of American, French, and German athletes who were counted among the world elite in windsurfing at that time. A number of them ranked among the pioneers of windsurfing and had been involved in the movement from its beginning. They all participated in international competitions (World Cup, Grand Prix, etc.) as professional windsurfers. They could perform the front loop reliably and variably in a competitive setting (some as a double frontal loop) and trained for about 30 weeks annually. Expert status was defined as the ability to perform front loops on a competitive level for at least 7 years.

The 20 novices (18 males, 2 females; mean age: 22 years; engaged in windsurfing for 8.2 years on average; front loop on average for 1.6 years) were mostly German and American athletes. They trained for approximately 23 weeks annually and participated in national and international competitions. However, they had no rankings worthy of mention and were unable to perform the front loop under competitive conditions. Overall, their (potential) scope for development was comparable to the expert group. Hence, these were persons with the capability to reach an expert level who had not got there yet. The main aspect for the present study was that the novices mastered the technical execution of the front loop far less reliably and regularly than the experts. Experts stated that mastery depends highly on experience in windsurfing and repeated practice under various conditions. The minimum condition for acceptance in the novice group was to have performed the front loop at least twice (according to their own reports).

The results of this study are illustrated in Figures 15.8 through 15.10. For this illustration, a is constantly set at 5%; this equals *a* $d_{r\cdot t}$ value of 3.51.

Figure 15.8 displays the group structure of the experts based on cluster analysis in the form of a dendrogram and reports the factor matrix arranged according to clusters. There were three clusters. The structures of mental movement representation in the expert group showed a remarkable affinity to the biomechanical functional structure of the movement. As Figure 15.8 shows, the functional structure of the movement could be divided into several phases. *Takeoff* could be classified as a second-order supportive phase, *preparation of rotation* as a first-order supportive phase, and *rotation* as the main phase. The superordinate concepts acquired on the basis of clusters (takeoff, preparation of rotation, rotation) are spatially distinct and organized in a temporal sequence. We assume that they serve as a means to solve specific subproblems (energizing, introduction of impulse, rotation).

Figure 15.9 illustrates the cluster solution for the novice group. These cluster solutions reveal a weak structural link between elements. The BACs were located slightly above the critical distance (d_{crit} = 3.51). Therefore, no structure could be proven for the whole group.

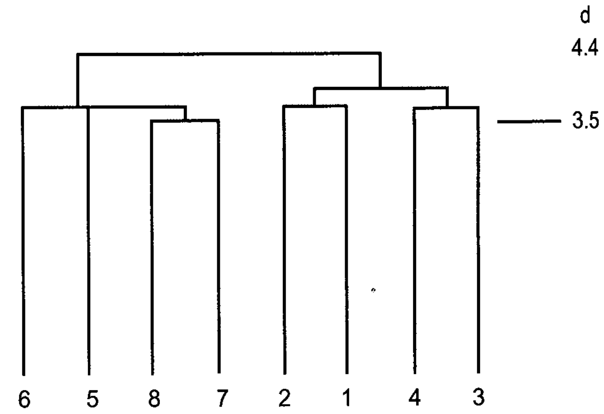


1. High-low-high; 2. Takeoff; 3. Open the sail;
4. Center of gravity to the front; 5. Introduction of rotation;
6. Becoming compact; 7. Shift sail; 8. Turn head

Figure 15.8 Results of the hierarchical cluster analysis of BACs for the front loop in the expert group. The lower the value of an interconnection between the study units (see the Euclidian distance scale on the right), the lower the distance of the concepts ($n = 20$; $\alpha = 5\%$; $d_{crit} = 3.51$).

Obviously, the technique-related representational structures were too weak at this point. The claims regarding movement representations in individual cases are particularly interesting for technical preparation.

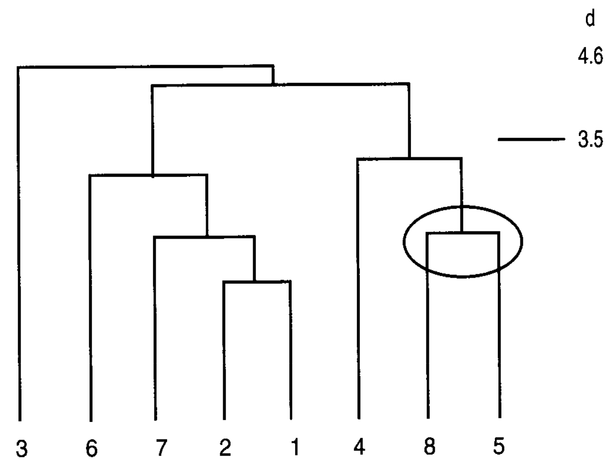
The dendrogram of the novice revealed a significant difference in the clusters compared with that of the expert group. Whereas the expert cluster solution followed a functionally based phase structure of the movement, no comparable structure could be found in the novice. Here, elements were arranged differently, and neither a phase-related clustering nor a temporal-sequential structure could be seen. Furthermore, inexpedient mental structures were apparent. Subject 4 (see Figure 15.10) combined elements from different movement phases. This resulted in a cluster consisting of elements 5 (rotation) and 8 (head turn). Although both elements of the cluster represent rotary motions, they have nothing in common regarding functional aspects. Whereas element 5 plays an important part in the introduction of the rotation, element 8 completes it. Obviously, surface features, not functional features, were consulted when classifying the elements. The unification of these elements on the representational level is often linked to typical movement errors on this level of motor learning (rough coordination). In this context, novices often forget the head turn needed to complete the movement, and this usually leads to dangerous falls.



1. High-low-high; 2. Takeoff; 3. Open the sail;
4. Center of gravity to the front; 5. Introduction of rotation;
6. Becoming compact; 7. Shift sail; 8. Turn head

Figure 15.9 Results of the hierarchical cluster analysis of BACs for the front loop in the novice group ($n = 20$; $\alpha = 5\%$; $d_{crit} = 3.51$).

In this study, we were able to confirm the relation between cognitive representation and performance for a special movement technique. The cognitive structure of persons with high ability is more differentiated, and more strongly function-oriented, than that of beginners. Experts obviously are better able to apply their knowledge in prac-



1. High-low-high; 2. Takeoff; 3. Open the sail;
4. Center of gravity to the front; 5. Introduction of rotation;
6. Becoming compact; 7. Shift sail; 8. Turn head

Figure 15.10 An individual novice's (Subject 4) solution in the learning stage of rough coordination as an outcome of hierarchical cluster analysis. The circular mark denotes a link between two elements that is obviously based on surface features ($\alpha = 5\%$; $d_{crit} = 3.51$).

tice when aiming for optimal execution of the movement. Furthermore, we find statements on cognitive structures that are directly relevant for training processes. These statements can help a coach to decide which cognitive context athletes can understand and work on. This statement is particularly relevant for movements that have to be carried out under extreme time pressure and presumably make use of their nondeclarative knowledge.

Consequences for technical preparation can be derived from such analyses of the representational structures and biomechanical structures of a movement. It becomes possible to ascertain the phase of the movement in which representational problems are located. Then technical preparation can train precisely this motion sequence. A specific teaching method has been developed for this purpose (Garzke, 2001; Schack & Garzke, 2002).

The first step is to imitate the whole movement. Initially, the judo somersault is perfectly suitable for training the frontal direction of rotation and motion. Practicing this movement trains and stabilizes the structure of the front loop. Further focal points in this exercise are the acquisition of coordination and rhythm during rotation. Training here focuses on those movement components that were found to be poorly structured in representations. The persons whose representational structure is illustrated in Figure 15.9 have to focus their training particularly on the rotation phase. It is crucial for athletes to experience what the optimum movement structure feels like. They can experience that turning the head is not immediately connected with the rotational impulse. The person with difficulties in executing this (see Figure 15.10) learned to integrate the intermediate steps, *becoming compact* and *shifting the sail*, into the movement.

The next main step is to execute the judo somersault with the rigging. This is a way to further improve the movement structure. Incorporating the rigging brings the practiced movement closer to the targeted movement on the water. Again, this method is designed to work on the tactile movement effects. The athlete should achieve a further improvement regarding the movement structure.

The next step of technical preparation is to perform the exercise with a wooden board and rig. This exercise increasingly improves the center of gravity in the direction of the correct movement execution in the water.

Those movement elements that have proved problematic in the representational structure can be trained specifically. The athlete should move from this suboptimal movement structure to an optimal movement structure. In this way, the execution of the movement can be trained by, for instance, . special surveillance of shifting the center of gravity to the front, grabbing the sail close, or becoming compact (for more details, see Schack & Bar-Eli, 2005).

When the movement structure has been acquired up to this point of technical preparation, we suggest that the SDA-M method should be reapplied to examine the athlete's representation structure. This analysis can provide indications for further steps of technical preparation. At this point, the representation structure should be close to the expert's structure-at least in terms of its basic organization (see Figure 15.8). If major problems should still be apparent in the representation structure, we recommend moving technique execution and movement representation back to step 2 or even step 1, depending on the extent of the problems. If movement structure and representation structure prove to be stable, we proceed to step 4. Here, the movement is executed on sand dunes, introducing the wind as an additional factor. This exercise aims to stabilize the movement structure. In particular, utilizing the wind makes the basic technique available to the athlete under an increasing variety of conditions. The athlete now must apply the acquired basic technique under varying environmental circumstances as a means to secure a stable movement. In this step of technical preparation, it is additionally crucial to learn about the functional importance of the head as the leading instance in the movement. Athletes who do not turn their head over the distal end of their shoulder will land on their back because of the lack of rotational impulse. Athletes who turn their head toward the back of the neck during initialization of the movement will stop rotating and crash onto the water surface. On the shore, damage will be limited, but, overall, the correct movement of the head is an important cornerstone in the optimal movement structure. It is essential that the head be turned in the rotation phase and the horizon sighted.

The next step of technical preparation of the front loop is practicing it on the water. Here, the speed loop can be performed as the last preparation step. The speed loop is comparable to a skidding sideways purler, in which the board is pulled after the body. This involves an increase in the variability of the movement execution. Thus, the aim is a variable accommodation to varying environmental conditions. Herein, we attempt to further stabilize the structure of the movement. After this step, we move back to direct practice of the front loop. After a certain practice phase, or if problems show right after beginning the exercise, we incorporate the SDA-M method again to measure and evaluate the representation structures.

As this representative example of individual sport shows, the acquisition of representation structures can make a major contribution to the optimization of technique training. As measurement takes only about 15 minutes and results of the analysis are available immediately, many opportunities arise for technical preparation.

A further step in technical preparation is to conceptualize a mental training that begins with the representational structure of the athlete. Such a mental training based on mental representation takes account of the individual dispositions and concerns of the athlete.

NEW PATHS IN MENTAL TRAINING

Studies carried out during the first half of the twentieth century already revealed indications that performing tasks mentally leads to improvements in subsequent test performance (e.g., Sackett, 1935). Various fields of sport psychology have continued such research systematically, particularly since the 1960s (see, e.g., the meta-analysis of Driskell, Copper, & Morgan, 1994). The use of mental training in top-level sport has become particularly prominent.

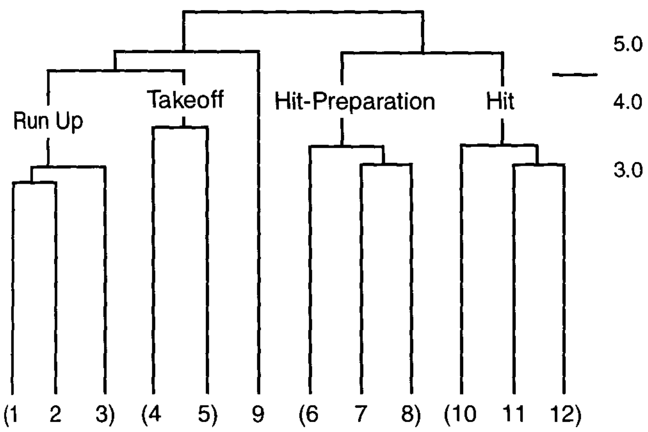
Various theories have been used to explain the effects of mental training (see, e.g., Driskell et al., 1994; Heuer, 1985). The major explanatory models based on current scientific findings can be differentiated according to whether they consider effects to be due to physically peripheral (neuromuscular) processes or central mechanisms (e.g., symbolic codes or programs). Our findings on the architecture of action extend the work on ideomotor action (Knuf et al., 2001; Koch et al., 2004) and current neurophysiological findings (Jeannerod, 1995, 2004) and open up a new explanation for the effects of mental training: the *perceptual-cognitive hypothesis.* This hypothesis posits a representation system in which more strongly cognitive representation units (nodes) are linked to perceptual representations (e.g., kinesthetic, optical, or acoustic effect codes). Because they possess a spatiotemporal structure, these representations can be translated directly into movement. This makes additional motor, spatial-pictorial, or other representations (see, for the symbolic hypothesis, Heuer, 1985) unnecessary for movement control. A further basic assumption of this model is that imaging a movement and performing it are based on the same representations (Jeannerod, 1995; Schack, 2002). This hypothesis explains the impact of mental training by proposing that it internally activates and stabilizes the representation system. Mental simulations of movement may forge, or strengthen, links between cognitive representation of intermediate states of the movement and the accompanying perceptual effect codes. At the same time, interfering perceptual inputs will be inhibited. Because these representations are conceived as being located on a hierarchy of levels, mental training also initiates feedback processes between various representation levels (see Jeannerod, 1995).

This makes the methods developed here (e.g., SDA-M) directly significant for developing new forms of mental training. The main disadvantage of traditional procedures is that they try to optimize performance through repeatedly imagining the movement without taking athletes' mental technique representation into account (i.e., they are representation-blind). However, if the movement's cognitive reference structure has structural gaps or errors, these will tend to be stabilized rather than overcome by repeated practice. The alternative developed here is to measure the mental representation of the movement before mental training and then integrate these results into the training. This mental training based on mental representations has now been applied successfully for several years in professional sports such as golf, volleyball (Schack, 2004a), gymnastics (Heinen, Schwaiger, & Schack, 2002; Schack & Heinen, 2000), and windsurfing (Schack & Heinen, 2000).

A contemporary study conducted in professional volleyball addresses the spike. This movement requires at least 12 substeps (BACs) that are stored in memory. Our primary focus is on the memory structure of the movement. In preparation for a mental training program, we studied this structure in the members of a Women's Volleyball Youth National Team. Figures 15.11 and 15.12 illustrate the results for two players who are both outside hitters.

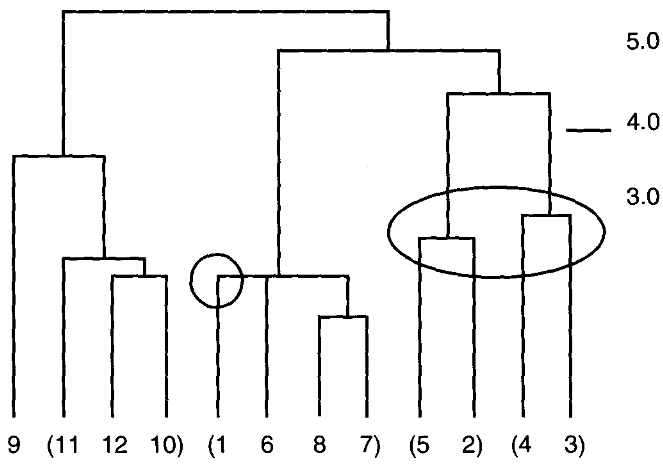
Player A (Figure 15.11) holds a clearly structured, almost ideal movement representation in her movement memory. Basic action concepts 1 through 3 in connection with 4 and 5 form the *run-up* phase. Concepts 6, 7, and 8 combine for the *hit-preparation* phase, and 9, 10, and 11 make up the *hit* phase.

Player B (see Figure 15.12) had had difficulties in optimally executing the spike for several years. Our analysis reveals the cause: BACs 1 through 3 and 4 through 5, which are important for the sequence of impulses during run-up and takeoff, point to a less precise memory structure. For this player, run-up and takeoff are broken down into two inefficient memory sections (5-2 and 4-3). Subsequently, an individualized mental training program tackled the memory structure and developed movement imagery for an ideal takeoff and a proper spike. Additionally, the player went through a series of run-up and takeoff drills designed to bring out the optimal motion sequence. The focus was on making the player aware of the altered movement so that she could develop a new feeling for it. We subsequently



1. Taking arms back; 2. Stamp step; 3. Bending knees and trunk; 4. Swinging both arms forward; 5. Extending legs; 6. Body arching; 7. Spiking arm back; 8. High elbow; 9. Glance toward opponent 's block; 10. Spike emphasizing the wrist; 11. Whipping extension of arm; 12. Drawthrough of hitting arm

Figure 15.11 Memory profile of the spike in Player A's movement memory. The numbers correspond to the BAC numbers (see text). A scale indicating the distances of BAC representations in movement memory is located on the right side of the figure. The lower the value of a horizontal connection between two BACs, the lower the distance between them in movement memory. *Source:* "Cognitive Architecture of Complex Movement," by T. Schack, 2004, *International Journal of Sport and Exercise Psychology, 2*(4), p. 417. Reprinted with permission.



1. Taking arms back; 2. Stamp step; 3. Bending knees and trunk; 4. Swinging both arms forward; 5. Extending legs; 6. Body arching; 7. Spiking arm back; 8. High elbow; 9. Glance toward opponent 's block; 10. Spike emphasizing the wrist; 11. Whipping extension of arm; 12. Drawthrough of hitting arm

Figure 15.12 Memory profile spike for Player B. *Source:* "Cognitive Architecture of Complex Movement," by T. Schack, *International Journal of Sport and Exercise Psychology, 2*(4), 2004, p. 430. Reprinted with permission.

aimed to generate this optimal perception of the movement in the complementary mental training as well. This succeeded in improving Player B's spike significantly, and she is now a member of the Women's A-National Team. The advantage of this combination of mental training and memory analysis consists in the fact that athletes' memory structures are integrated into mental training providing sufficient consideration of their individual dispositions.

Mental training is now being applied not only in various professional and amateur sports but also in rehabilitation. In cases of injury, mental training offers a means of training even when active movement execution is severely impaired. As a result, new opportunities for the use of mental training have opened up in the fields of medical and orthopedic-traumatologic rehabilitation. In this context, mental training has proved to be of great use when it comes to regaining lost movement patterns after joint operations or joint replacements. Moreover, it can also be applied successfully in neurological rehabilitation for stroke patients by stabilizing and gradually improving their grasping movements. Thus, mental training provides a general means to link together imagery and movement in various areas of life.

ACTION-BASED STRATEGIES OF PSYCHOLOGICAL TRAINING IN APPLIED SPORT PSYCHOLOGY

Theoretical considerations regarding the construction of action are also helpful when trying to identify suitable psychological training methods for applied work. As before, we start by using specific diagnostic procedures to investigate the systems involved in the organization of action. Diagnosis and training methods on the mental representations level have previously been discussed at great length. In this context, it is important to note that we also apply the results of such experimental diagnoses in the consulting process so that athletes receive feedback on their memory structure (see Figure 15.13).

This diagnosis is important when deciding whether an athlete possesses good dispositions for optimal process regulation. Problems regarding the capacity to perform in competitive settings may be located in the field of process regulation, as well as in basic regulation. The term *process regulation* refers to the execution-related organization of an action, whereas *basic regulation* describes the generation of emotional and motivational conditions for the action. Basic regulation is primarily produced at the level of mental control. Therefore, we applied appropriate diagnostic tools to test components such as stress regulation,

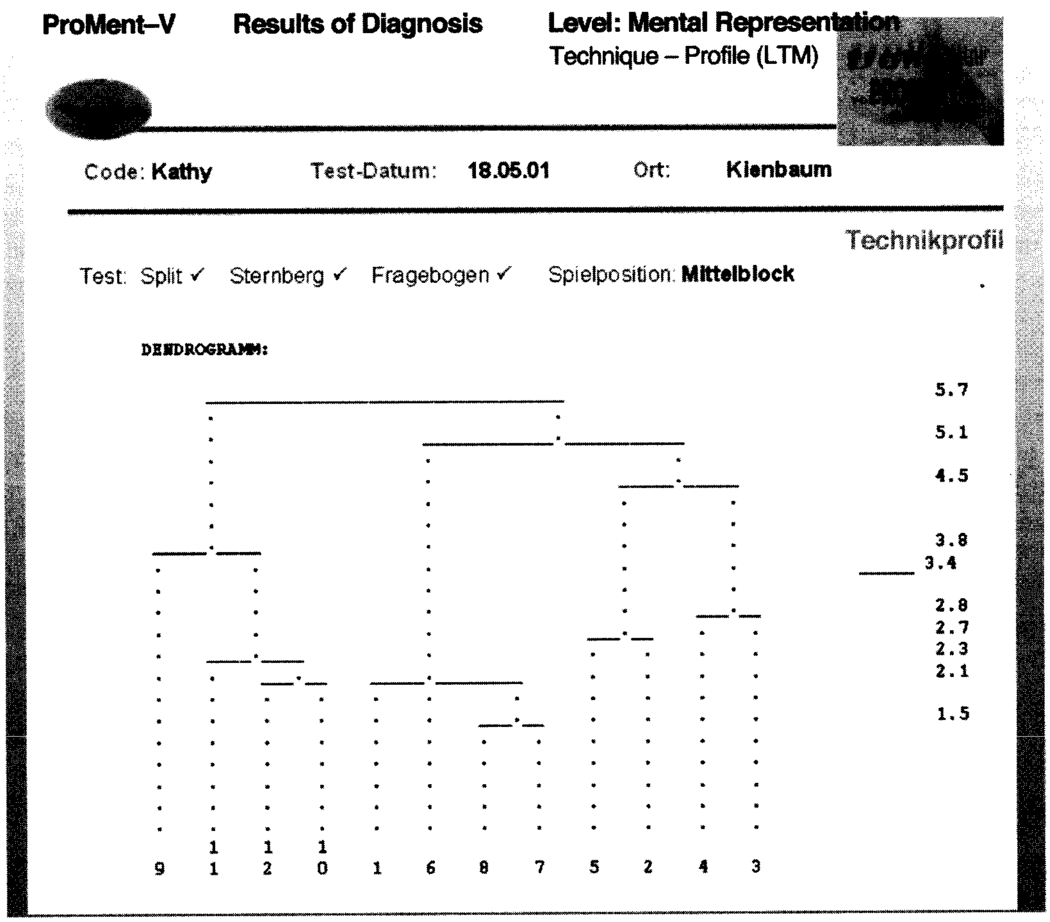


Figure 15.13 Results of the experimental diagnosis of mental movement representations for an athlete from the German National Team.

competition anxiety, self-talk, and different components of volition. The results are given to the athlete as a mental profile (see Figure 15.14).

Such results can be used to make better decisions on appropriate psychological training methods. If problems are diagnosed on the level of mental control, training methods to develop mental control should be preferred. These may be exercises to optimize self-talk, relaxation methods, or procedures for optimizing stress regulation. If problems concerning movement memory and motor coordination are diagnosed on the level of mental representations, imagery training or technical preparation would be more appropriate.

COMPUTER-BASED METHODS IN APPLIED SPORT PSYCHOLOGY

The development of digital video techniques has created a variety of new opportunities for analyzing and improving actions in sport, particularly in the field of mental training and technical preparation. As well as just displaying moving images, digital supplementation and the analysis of video images offer the greatest new perspectives. In this section, we introduce and systematize some of the computer-based procedures for visual feedback used in praxis.

Computer-based procedures for visual feedback can be subdivided into three groups (Seifriz, Schack, & Mester, 2004):

1. *Presenting video sequences subsequently or simulta neously:* Simultaneous forms of presentations are split-screen and cross-fading procedures. In the split-screen procedure, the two sequences to be compared are shown side by side on the screen. Cross-fading provides a playback of both sequences in one video (Figure 15.15). Such procedures are particularly appropriate to reveal differences in speed in, for example, downhill skiing. Furthermore, the simultaneous display also shows differences in movement

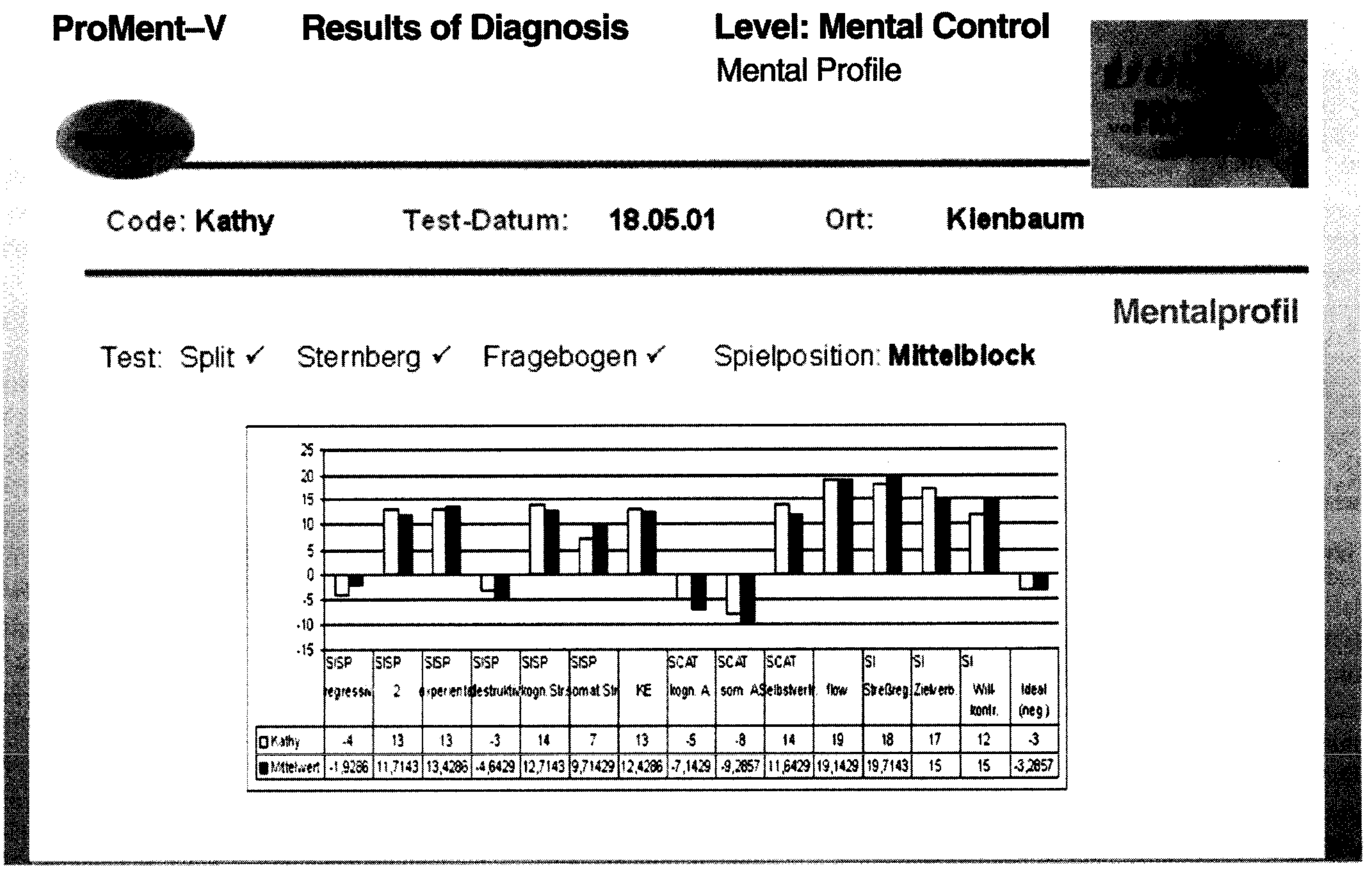


Figure 15.14 Results of a mental control diagnosis. The athlete receives feedback as a mental profile, indicating both own test results and mean results for all athletes in the specific playing position. These results are from the German Volleyball National Team. Each subtest (e.g., SCAT, sport competition anxiety test) has a scale. Emotional or motivational conditions that are rather negative (e.g., anxiety) are displayed as negative trends (below 0).

techniques. This makes it easy to emphasize key points and errors in motion sequences and use these to provide additional information in technique training.

2. *Adding movement paths to the video sequence: By* utilizing tracking procedures (see Intel, 2001) to follow objects on the basis of their structure and/or color information, movement paths of athletes or pieces of equipment can be recognized and highlighted in the video image. This can render visible movement paths that cannot be recognized directly or are extremely long. Figure 15.15 displays the tracked lanes of two downhill skiers using the cross-fading procedure.

3. *Creating and visualizing movements and movement paths on the computer screen with the help of mathematical models and simulated arithmetic (Seifriz, 2001):* Starting with tracked movement paths and kinematic analyses, optimized movement solutions can also be presented visually and compared with real movements. Figure 15.16 shows an image taken from an animation of an optimized lane on a slope created via GPS measurement. Such artificial tracks give athletes an opportunity to view alternative lanes and thus provide new impulses for future movement executions.

In numerous sports, these methods belong to routinely applied procedures in training and competition. There is a great interest in these methods from the mass media, and trainers now use some of these procedures on a regular basis.

As pointed out earlier, it is particularly important for coaches to possess information on their athletes' movement imagery (representation) and to influence this through technique training. For this aspect, we can assume that functional relations exist between experimentally acquired movement representations and kinematic parameters of movement execution (Schack, 2003).

On the basis of such considerations, we have further examined how to construct a modular measuring set that

Figure 15.15 Tracking of lanes using the cross-fading method.

would support motor learning processes by combining the kinematic analysis of movement technique with the analysis of mental parameters and applying these in technique training. We have called this modular measuring set eBRAIN (translated into English: enhanced movement representation analysis inventory; Schack & Heinen, 2002).

Selected modules from e-BRAIN are acquirement of technomotor knowledge stock in long-term memory and acquirement of reaction time in short-term memory (SDAM and CMC method; Schack, 2002). These experimental methods for the analysis of movement representations are supplemented by an analysis of movement kinematics (Heinen & Schack, 2003; Knoll, 1999). By using a subsequent simulation of isolated movement sequences, it becomes possible to illustrate new and optimized movement solutions and thus supplement technique training.

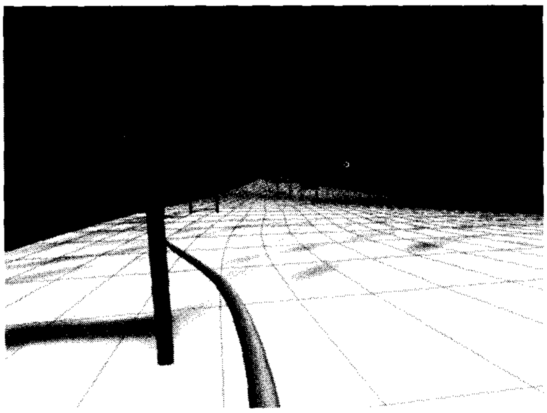


Figure 15.16 Visualization (animation) of simulated lanes.

To link kinematic and mental parameters, complex illustrative functions can be generated. Connections between parameters of movement kinematics and mental representations have been confirmed in apparatus gymnastics and volleyball (e.g., the prediction of the occurrence of the tipping angle in twisting somersaults based on data acquired through SDA-M analysis). This data can be transferred to an individual-oriented mental training program (Schack, 2002).

Module 1 of e-BRAIN contains the method for measuring mental movement representations presented earlier. These data provide vital information for technique training because they highlight the mental framework of movement organization. In contrast, the movement can be illustrated through biomechanical measurement procedures (Module 2). The parameters collected in this way form a complex yet structured web of parameters. The aim of e-BRAIN is not just to acquire such parameter webs separately, but also to establish a connective function between the pools of values (representation-related and biomechanical data), to use them as feedback in technique training, and to utilize them for simulations.

Figure 15.17 shows the measuring set design of e-BRAIN. On the left, we find the representation structure of the volleyball hit in an athlete's long-term memory. The center features a 3-D clip of his movement execution. These clips also constitute the basis for the analysis of

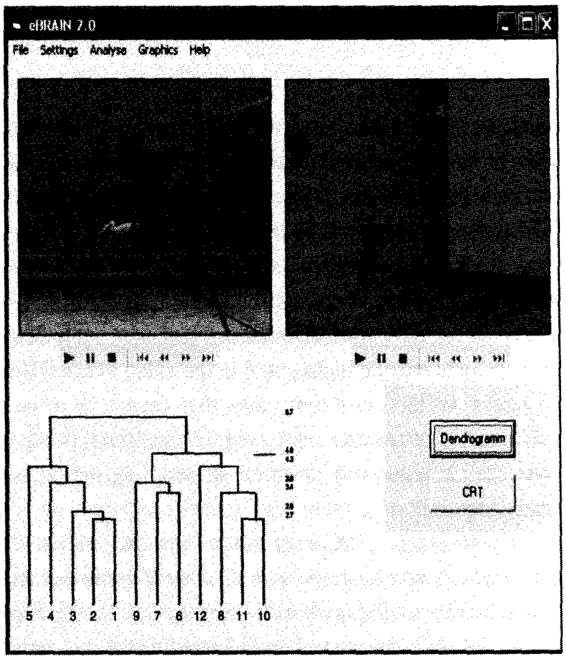


Figure 15.17 Split-screen presentation of e-BRAIN.

movement kinematics used to report the movement via an animation and simulate partial aspects of the movement (as in the context of technical errors; on the right). As a consequence, e-BRAIN not only provides data on the athlete's movement organization (structure of movement representation, kinematic data, and linkage of both sets of data), but also delivers clear information (Figure 15.17) that can be used as visual feedback.

CONCLUSION

This chapter has shown how the practical work of sport psychologists requires a theoretical foundation and intervention techniques based on appropriate methods. Such a perspective views theory as an instrument to be applied in practical work. Such an instrument either has to prove its worth or be further investigated and developed. In applied sport psychology, this results in a decisive triad composed of theory, technology, and practice.

To back up the techniques of sport psychologists, we present several methods that focus on precisely defined components of an action. It is clearly advantageous for a coach to know how mental structures form, stabilize, and change in sport action. A coach who possesses such knowledge is also better able to address the individual athlete on his or her current level of learning and shape instructions specifically so that the athlete understands them. The methods presented here make it possible to take the essential information on the underlying cognitive-perceptual action system into account and address the individual needs of an athlete in a better way. The theoretical perspective on the construction of action developed here (Schack, 2004a, 2004b) and the accompanying methods (technological steps) are therefore relevant not just for optimizing the daily work of the sport psychologist but also for opening up new perspectives to modify approaches to mental training and technical preparation.

The development of computer-based methods in applied sport psychology is also based on conceptual models of the construction of action. With the video-assisted presentation of movements, we try to influence precisely defined components of the action system (representations). Once these components have been defined, we can reap the benefits of new digital methods in applied sport psychology.

In the present approach, those working in applied sport psychology should try to be not only excellent scientists but also excellent practitioners. Although those engaged in applied sport psychology are naturally more interested in the practical field, they should not forget that the outcome of practical work depends decisively on whether the coach or the sport psychologist possesses a sound theory.

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