When looking at the practice of sport it becomes obvious that the success of an individual athlete or a team is highly dependent on how well the essential techniques of the sport are applied and mastered. Michael Jordan always impressed people with his sure and accurately mastered shots. Dick Fosbury paved the way to entirely new dimensions in high jumping by developing a whole new run-up and jumping technique. As a result of their amazing technical diversity, Brazilian soccer teams are very successful at the top international level. In contrast, certain athletes and teams repeatedly fail as a consequence of technical problems, while others never perform to their full potential due to insufficient technique. For these reasons, technical training plays a central role in competitive sports. It can be claimed that the effect rather than the technique of a movement ought to be the decisive criterion for success in sport, and therefore for individual movement organization. One must agree with this. Hence, it is crucial for athletes to target their objectives and strive to achieve them in practice as well as in competition. Within certain limitations, the motor system of an athlete organizes itself in relation to this aim. Yet, it is usually too costly and also too risky to wait until this self-organizing system selects the optimum movement variant from the multitude of available variants on its own. Therefore, technique training serves as a means to stimulate learning processes in athletes that assist them in using their body, so that the desired effects can be accomplished in the most effective manner.

Technical preparation has hardly been the focus of scientific literature within the Anglo-American linguistic boundaries. There, the relevant topics were rather titled skill learning, skill acquisition, and skill training. However, a more precise look at different studies in this field reveals that research was usually concerned with movements of low complexity in laboratory settings. Furthermore, technique training is closely connected with the question of how body coordination can function optimally in competition and under practice conditions, and how the targeted technique is structured. As early as 1985 Newell criticized the fact that all issues in the skill acquisition domain focused on the problem of movement control (Newell, 1985). Thus, substantial questions that made up the scientific basis of technical preparation were mostly left out. Newell (1991, p. 109) states: 'The study of the establishment of structure in movement and the learner's search for stable modes of coordination has not been an issue for traditional theories of motor skill acquisition.' Questions such as how the structure of movement is shaped and how stable modes of coordination for the solution of movement tasks evolve represent a central theme of technical preparation. This chapter focuses on the acquirement of technologies in this field.

Intensive study of different fields of technical preparation is traditionally to be found in the scientific literature from Eastern Europe (e.g., Starosta, 1991; Sudilin, 1980) and later more frequently from Germany (e.g., Daugs, Mechling, Blischke, & Olivier, 1991; Martin, 1992; Mechling & Carl, 1992). Yet even here a closer look at the status of research reveals
that accounts of technical preparation are often contradictory and not concrete, or they remain reduced to partial analyses from a biomechanical standpoint. Therefore, an anthology by Nitsch, Neumaier, de Marées, and Mester (1997) took the first steps in the direction of an interdisciplinary regeneration of this field for German-speaking researchers. As technical preparation is always connected with the optimization of motor learning processes, a host of other prominent research topics established in areas of sport psychology are relevant, in addition to the formerly mentioned central field of technical preparation. These include, for example, feedback research (Magill, 2001; Salmoni, Schmidt, & Walter, 1984; Wulf, 1994; Wulf, Schmidt, & Deubel, 1993), the acquisition of learning strategies (e.g., Lidor Tennant, & Singer, 1996; Singer, 1988; Singer, Lidor & Cauraugh, 1993), the direction of attention during motor learning (Wulf & Prinz, 2001), and the establishment of routines (Schack, 1997; Schack, Whitmarsh, Pike, & Redden, 2005). However, these more psychologically-oriented approaches have not yet been systematically applied to technique training.

In coaching practice, technical preparation plays an important role. Therefore, interdisciplinary models which provide concrete starting-points for the improvement of techniques are substantial for practical work. Coaches or practical sport psychologists would like to know how to stimulate stable modes of coordination in the athlete, how to stabilize proper techniques, and how to change previously acquired, inefficient movement patterns during training. All of these questions cannot be answered merely through biomechanical analyses or through detailed movement observations. In this context, relevant methods are rather those which comprehend and illuminate the cognitive-coordinative background of technique execution. This means that previous works regarding technique training have to be complemented through the addition of practice-relevant models and usable technologies and methods. This chapter will provide a contribution to this issue.

Thus, regarding the next section "Theoretical background of technical preparation," several steps have to be taken. After an initial clarification of terms regarding the field of technical preparation, model imageries concerning the construction of complex movements have to be created. It is important that these model imageries clarify at which levels of movement technique training starts and which role psychological factors play. After all, the aim is to provide the option to relate the formerly mentioned sportpsychological approaches - for instance, the establishment of learning strategies - through such a model. A further step will introduce current research methods which are particularly applied to the shaping of stable coordination modes, and thus become crucial for a central area of technical preparation. On this basis, an integrative perspective of technical preparation can be developed. This perspective shows how psychological factors are integrated into technical preparation. The section "Theoretical background of technical preparation" concludes with a display of a variety of starting points for the manipulation and optimization of psychological factors in technical preparation.

THEORETICAL BACKGROUND OF TECHNICAL PREPARATION
Technical Preparation - Definitional Issues
All technical achievement is built on diverse factors. In addition to psychological factors, further components are important. In Figure 1, technical performance is divided into three
substantial basic components: mental control, coordination, and physiological basis. Respective factors are assigned to each of these basic components. In this sense, physiological, coordinative, and psychological factors are of primary importance for technical performance.

Each of these basic components can be learned. This means that diverse factors can be developed. However, through this means of presentation (see Figure 1) it also becomes obvious that physiological, coordinative, and psychological factors cannot be discussed as completely separate issues, but that these factors interact in the bounds of technical and tactical performance. If, for example, Michael Jordan performs an optimal shot, these different factors have interacted in an effective fashion. Therefore, not only are single factors developed in the bounds of technical preparation, but their interaction is also optimized.

Although biomechanical analyses describe how a technique is performed, they do not provide valid claims about what an athletic technique is. Similarly, a comparison and separation of cognitive, physiological, and other components of technique organization doesn't seem helpful. After all, various factors interact during the execution of a technique (see Figure 1). Due to these and other concerns, we approach our definitions of athletic techniques coming from the movement task that is to be solved. Athletic techniques are optimum solutions for movement tasks. Accordingly, athletic action is something like the process of problem-solving, during which techniques are applied to achieve movement aims (see Bernstein, 1947, 1967, 1988, 1996a; Schack, 2002; 2004b). Thus, based on these works, it can be formulated that athletic technique represents a coordinative structure which is suitable for solving a concrete movement task. Hence, from a functional perspective, athletic techniques are nothing but approved ways for the achievement of movement aims under defined conditions. The conditions are strongly determined through the match- and competition-system, the environment, and through the athlete's individual disposition (see Newell, 1985; Nitsch, 1985).
Usually there is a technique model or a guiding technical imagery for athletic techniques. Such technique models (target techniques) can be found in textbooks, curriculums, and usually also in the minds of athletes and coaches. Technique models include the best solutions for movement tasks according to the current standards of knowledge. Yet one has to reason that an "ideal technique" can neither be achieved nor scientifically described (see Nitsch & Neumaier, 1997). The history of sport has shown that there have always been totally unanticipated new solutions for existing movement tasks (see, for example, the Fosbury Flop; Bar-Eli et al., 2006; Goldenberg et al., 2004). Therefore, established technique models (target techniques) are only useful as long as they help the athlete achieve an optimum coordinative structure for solving movement tasks. Hence, we propose to functionally incorporate target techniques into technique training, but not to treat them as normative factors in the training process.

What, in fact, are the functions of technique training? The essential function of technical preparation is to acquire motor skills and skill elements, to connect them structurally, and to apply them in solving a specific movement task. Further functions of technical preparation are to enable the variegation of learned techniques in a situation-appropriate manner, and to execute them in a stable fashion. The automation of technical processes is often referred to as another goal of technique training (see Martin, Carl, & Lehnertz, 1991; Mechling, 1988; Neumaier, 1997). Technical preparation is a process of several temporal-functional phases. Since techniques emerge gradually, the execution of a technique should improve with each phase in relation to the previous one. Bernstein (1947, 1996 a, b) has said that such motor learning is actually something like "repeating without a repetition." This means that technical preparation represents neither a repetition of the same motion sequence nor a facilitation of a particular technique. Technical preparation is rather a process, in which composition and structure of a movement develop. For this reason, technical preparation repeats the solution of the movement task in different variations and different stages, and the utilized means (motion elements) are gradually modified and improved (see Bernstein, 1996a). The next section will provide a concrete understanding of the functioning and construction of complex movement techniques.

For the acquisition and storage of complex movements, various usages of memory are important (Schmidt & Lee, 2005; Singer, 1980). During technical preparation, the memory serves the function of a referential system. Thus, learning is linked to the correction of memory structures and to the modification of neuronal structures (Jeannerod, 2004). In current studies, it became obvious that the structure of movement representations systematically changes during technique training (Schack, 2003b, 2004a, b). While a high variation and openness of memory structures is to be found in the initial phases, movement representations approach a temporally and spatially more ordered structure in advanced phases of technical preparation. Thus, an increasing amount of order can occur in movement memory. This order meets the requirements concerning movement execution. The cognitive reference structure in the memory increasingly resembles the movement structure of an optimally executed technique. Current neurophysiological studies add to these reflections and research results in a specific manner (Geourgopoulos, 2002; Hoffmann, Stoecker, & Kunde, 2004; Jeannerod, 1997; 2004; Koch, Keller, & Prinz, 2004; Schack, 2004a, b). Overall, this provides empirical evidence for the claim that in the bounds of technique training, a structure of the movement and a structure in the memory
Figure 2 The four phases of technique training.

are gradually established. Therefore, it is reasonable to think about phases of technique training.

Figure 2 provides a distinction of the four phases of technique training. The first phase is about the acquisition of the basic structure of a technique. Therefore, it is to some extent necessary to learn and practice single elements of motion. Besides basic structure learning, the second phase of technical preparation is predominantly concerned with automation of motion sequences. For this reason, attention capacities become more available and applicable for differential learning strategies (see Lidor, Tennant, & Singer, 1996). In the third phase, the focus lies with the stabilization of the technique and its variable application. For the technique to be applicable under various situational conditions, the conditions are purposefully variegated in this phase of training. For instance, in volleyball training, different indoor facilities and different balls are used, and different levels of illumination and artificial soundscapes are produced and incorporated into practice. In the fourth phase of technical preparation, the previous training phases can be extended through the development of technique styles. Thus, on the basis of secure and variable use of techniques, certain modifications of these techniques can be developed. Completely new and supplemental technical solutions are imaginable as well. If novel technical solutions are now sought for the same movement problem, technique training for the new technique starts over with the first phase. As an example, in the 1980s the Eastern Germans aimed at new technical solutions for jumping techniques on the vaulting horse, based on the variable mastery of traditional jumping techniques. Among other things, these new techniques already included the execution of somersaults in the first phase of the jump. Due to the high load on the athlete who had to land on the vaulting horse and depart from it, these techniques did not win recognition (see Krug, 2004).

However, the sequence of technique training must not be imagined as a one-way street. It is often necessary to take a step back and, for instance, return from basic-structure stabilization to basic-structure learning. This becomes particularly important when technical flaws have crept in.

In response to these phases of training one can distinguish among three different forms of technique training: (1) technique acquisition training (phases 1 and 2); (2) technique application training (phases 3 and 4); and (3) technical supplementary training (see Martin, 1991). Technique acquisition training aims at the basic structure of the technique. In contrast, technical application training is oriented towards stabilization and variable application of the technique. In this stage of training, situation-appropriate anticipations play an increased role. Accordingly, the technique acquired in technique acquisition
training is increasingly incorporated into match situations and tested therein. These newly-learned techniques are subsequently connected to already existing techniques. For example, new offensive techniques in volleyball can be acquired with no connection to concrete match situations (technique acquisition training). Yet technique application training is concerned with the application of these techniques in concrete match situations, their variable application - depending on actions token by one’s own team and the opposite side, and their combination with existing techniques. For example, anticipatory capacities, which play only a subordinate role during technique application training, become necessary for this aim. In technical supplementary training, coordinative abilities (such as the ability to rhythmic organization in dance and gymnastics), which are essential for the execution of movement training, can be trained. Moreover, forms of mental training such as imagery training must be counted towards this kind of training (see chapter 6 in this book), as well as the application of learning- and attention-strategies (Singer, 1985; Singer, Lidor, & Cauraugh, 1993, 1994; Wulf & Prinz, 2001), or the development of routines (Schack et al., 2005). Psychological factors are decisive in all three forms of technical training. To be able to mark the function of these psychological factors regarding the establishment and maintenance of technical performance more precisely, the construction of movement techniques will be discussed in the next section.

THE CONSTRUCTION OF MOVEMENT TECHNIQUES

In the lost section it became obvious that movement techniques are not "ground in," but rather systematically built up within the bounds of technique training. This assumption is based on works discussing neurophysiological stages of movement organization (Bernstein, 1947; 1 996a, b; Gurinkel & Cordo, 2002; Jeannerod, 1995). Another group of research was able to show that cognitive-perceptual structures play a remarkable role in motor learning (e.g., Mechsner, Kerzel, Knoblich, & Prinz, 2001; Prinz, 1997; Schack, 2002, 2003b; Schmidt & Lee, 1998; Singer, 1980; see also Schack & Tenenbaum, 2004a, b). With reference to these works, the construction of movements will be further clarified at this point, especially regarding psychological factors. For this purpose, we will deal mainly with the question of how structural components of psychology are integrated into the construction of techniques, and which functional role they play in the maintenance of technical performance.

As known from practice and as described by Eastern (Bernstein, 1947; Luria, 1992; Vygotsky, 1992, orig. 1929) and Western (Ach, 1921; Rosenbaum, 1985; Singer, 1980) scientists, one major property of complex movements is their volitional character. Human volition (or will) can be analyzed functionally and broken down into its main components. From the functional perspective taken here, we shall call this ability (volition) mental control. One major functional component of mental control is the encoding of the intended action goal. Such a coding is needed before an action goal can adopt the function of a cognitive benchmark for the further process. This intention-related coding is followed by the generation of a mental model of the future to which all control and monitoring processes can be related. Strategies like inner speech strategies (Schack, 1997), learning strategies (e.g., Singer, 1985; Singer, Lidor, & Cauraugh, 1993, 1994), and attentional
strategies (Wulf & Prinz, 2001) are a further functional component of mental control. These are applied particularly when difficulties emerge in action performance. They are a means of stabilizing activities leading toward the goal. Hence, they are important for the development and maintenance of movement techniques. This is the reason why such strategies have to be developed in the bounds of technical (supplementary) training. If we provisionally locate these functional components of voluntary movement regulation on a level of mental control, we still have to ask in what form the knowledge is integrated into behavior control. This is because knowledge plays a central role in storing the movement structure. The development and stabilization of functional coordination structures are regarded as the central task of technical acquisition and technical application training. These stable coordination modes utilize memory structures. The decisive question is how technique-related memory structures are integrated into the whole system, how they can be volitively addressed, and which role they play in the automatization of technical processes.

From our perspective, conscious mental functions can be assumed to emerge on the basis of elementary functions. Hence, whereas elementary functions (e.g., automated processes, reflexes) are influenced directly by stimulus constellations, mental control functions are guided intentionally - the self regulates them. This points to the vertical dimension of cognitive control. It is assumed that the functional construction of actions is based on a reciprocal assignment of performance-oriented regulation levels and representational levels (see Table 1). These levels differ according to their central tasks on the regulation and representation levels. Each level is assumed to be functionally autonomous.

Table I Levels of Movement Techniques

<table>
<thead>
<tr>
<th>Code</th>
<th>Level</th>
<th>Main function</th>
<th>Subfunction</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>Mental control</td>
<td>Regulation</td>
<td>Volitional initiation control strategies</td>
<td>Symbols; strategies</td>
</tr>
<tr>
<td>III</td>
<td>Mental representation</td>
<td>Representation</td>
<td>Effect-oriented adjustment</td>
<td>Basic-action concepts</td>
</tr>
<tr>
<td>II</td>
<td>Sensorimotor</td>
<td>Representation</td>
<td>Spatial-temporal adjustment</td>
<td>Perceptual effect-representations</td>
</tr>
<tr>
<td>I</td>
<td>Sensorimotor control</td>
<td>Regulation</td>
<td>Automation</td>
<td>Functional systems; basic reflexes</td>
</tr>
</tbody>
</table>

The function of the mental control level (IV) has already been sketched for voluntary movement regulation and the coding or the anticipated outcome of movement. The level of mental representations (III) predominantly forms a cognitive benchmark for the mental...
control level (IV). It is organized conceptually and is responsible for transferring the anticipated action outcome into a model of the movement structure it requires. Because an action is "no chain of details, but a structure subdivided into details" (Bernstein, 1988, p. 27, translated), movement organization has to possess a working model of this structure. The corresponding abilities for using movement representations have been acquired stepwise during technical preparation. These movement representations hold the knowledge that relates directly to performance. However, the model also clearly reveals that these representations are functionally embedded in further levels and components of action organization. Therefore, the functioning of the lower levels (I and II) will also be sketched. The level of sensorimotor control is linked directly to the environment. In contrast to the level of mental control (IV), which, as explained above, is induced intentionally, the level of sensorimotor control (I) is induced perceptually. This can be illustrated in studies of patients whose range of movement is restricted through injury or illness (see, e.g., Leontjev & Zaporoshets, 1960; van der Weel, van der Meer, & Lee, 1991). Leontjev and Zaporoshets studied patients whose elbow and shoulder movements were limited because of peripheral nerve injuries. They found that the ability to move the dominant arm differed as a function of the concrete feedback obtained from the environment. For example, these patients could move their arm further when their eyes were open than when their eyes were closed. Their range improved even further when they had to touch a point on a screen. However, their range was greatest when they had to grasp an object. This study reveals vividly that the execution of movements can only be considered in the context of the intended sensory effect. Several studies concerned with the focus of attention in motor learning (e.g., Maddox, Wulf, & Wright, 1999; Wulf, Lauterbach, & Tool, 1999; Wulf & Weigelt, 1997) point in a similar direction.

The reason why a level of sensorimotor representation is necessary in this context is obvious. It can be assumed that this is where, among others, the modality-specific information representing the effect of the particular movement is stored. As we know from practice the relevant modalities change as a function of the phase of technical preparation and as a function of the concrete task. Representations involving the kinesthetic modality should also be assigned to this level. Such representations play an important role in the development and improvement of the feeling for movement, especially for water, balls, or a ski. This level involves the 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. Empirical evidence for such a perspective can be found particularly in recent studies on bimanual coordination (Mechsner, Kerzel, Knoblich, & Prinz, 2001) and in experimental studies on complex movements (Schack, 2002, 2003a; Schack & Mechsner, in press).

As the stage of mental representations plays a special role in the development of stable coordination modes in technical preparation, cognitive units of such representations shall now be examined more closely. The task of movement concepts is to classify movement stages that lead to certain effects, and thus it lies in the spatiotemporal control of movements. Drawing on experimental studies, these concepts have been labeled basic action concepts (BACs; see Schack, 2002). BACs are cognitive compilations of movements based on their shared functions in the attainment of action goals. They refer to perception-linked invariance.
properties of movements. Their characteristic set of features results from the perceptive and functional properties of movement effects. In this way, they ultimately serve to maximize the control of actions with the lowest possible cognitive and energetic effort.

In every technique a variety of submovements have become available for attaining intended action effects, and these can also vary in, for example, joint amplitudes. For instance, when learning to write, children solve the problem of equivalent submovements in a very simple way. They "freeze" their distal joints and thereby reduce the amount of equivalent movements and, finally, the degrees of freedom of the entire system (see Heuer, 1994). One can observe similar strategies in adults when forced to write with the nondominant hand (Newell & van Emmerik, 1989). The set of possible movements for attaining the goal is initially restricted to prevent control demands from being too high. Once cognitive units have been formed to control the movement, further, more complex, but nonetheless equivalent movements are permitted-the breadth of the concept is extended step by step. Accordingly, movements are functionally equivalent when one can substitute one for the other within the context of a behavior, without this threatening the behavioral goal. This is the case, for example, in volleyball, when the movement concept "extending leg" summarizes all movements that complete a take-off and prepare the hit. However, the relevant movements vary as a function of the player's position on the court, the positions of the opponents, and the current course of play. Hence, the movement concept "extending leg" summarizes all movements that functionally fulfill the same purpose when generating the hit. See additional examples concerning BACs in the following sections.

As we know from practice and from special studies, improvement in the domain of technical preparation is accompanied by order formation. In general, movement representations improve when problem-solving-related classifications (concepts) are formed. Hence, one can judge the technique-related order formation of movement knowledge. Such structures in action knowledge can be assessed and judged with the help of specific methods.

NEW METHODS FOR MEASURING PSYCHOLOGICAL FACTORS IN TECHNICAL PREPARATION

There are several psychological training practices which can be utilized in supplementary training (e.g., see chapter 6 in this book). However, during the acquisition and stabilization of coordination modes in technical acquisition, psychological factors usually receive little attention. Nevertheless, even in these fields, a functional link of motor learning and the development of suitable attentional and learning strategies (e.g., see Lidor et al., 1996; Wulf & Prinz, 2001) would be recommended. From our perspective, a substantial, previously unused resource lies in the field of psychological factors, which are directly involved in the construction of coordination modes of an athletic technique. If athletic techniques with a functional relation build up, stabilize, and change according to these memory structures, the key to motor learning processes in technical preparation is located right at this point. For instance, based on corresponding methods, the causes for incorrect
techniques could be detected in memory scripts. Concrete consequences for further development of performance, and therefore for the next step of technical preparation could be derived from such memory scripts.

When studying such kinds of movement knowledge in technical preparation, it is important to know their properties. One major property of knowledge in general and movement (tacit) knowledge in particular is that the structures of this action knowledge cannot be explicated directly. However, many methodological approaches to ascertaining such knowledge structures disregard this limitation. For example, expert research often studies action knowledge with survey methods such as interviews and questionnaires. However this ignores the fact that a major part of movement knowledge cannot be verbalized.

These and other problems with existing procedures led us to develop our own specific method. In line with the assumptions on the structure and dimensioning (feature assignment) of movement knowledge formulated here, this method is conceived as a structure-dimensional analysis-movement (SDA-M) of mental representations in movement organization. The SDA-M is a procedure that attempts to present the structure-dimensional relations of conceptually ordered knowledge psychometrically, for both single cases and groups (Lander, 1991; Schack, 2002). The following steps are necessary to assess the structure-dimensional relations between the BACs of a movement representation. The SDA-M method proceeds in four steps:

1. As with the methods discussed above, an SDA of a concept system initially seeks to gain information on the distance between selected representation units (concepts) that are relevant for a problem-solving domain. Because it can be assumed that the structure of movement representations can only be explicated to a limited extent, this is done with a special splitting technique. This is based on the selection and presentation of a group of concepts that are a valid component of that set of concepts that is absolutely necessary for a certain problem-solving or working domain. As in the methods mentioned above, this group of concepts is initially obtained through work analysis, survey, or experiment. This can be illustrated with an example of research in tennis, especially the tennis serve (see, also, the following sections). In a preparatory step, we characterised the task-adequate biomechanical organisation of the tennis serve and established a plausible and workable set of basic action concepts in collaboration with non-players, athletes of different levels, and coaches. The tennis serve consists of three distinct phases, each of which fulfils distinct biomechanical demands. First, in the pre-activation phase, the body and ball are put in position and tension energy is provided in preparation of the strike. The following BACs were identified: (1) ball throw, (2) forward movement of the pelvis, (3) bending the knees, and (4) bending the elbow. Second, in the strike phase, energy is conveyed to the ball. The following BACs were identified: (5) frontal upper body rotation, (6) racket acceleration, (7) whole body stretch motion, and (8) hitting point. Third, in the final swing phase the body is prevented from falling and the racket movement is decelerated after the strike. The following BACs have been identified: (9) wrist flap, (10) forward bending of the body, and (11) racket follow-through.
The experimental procedure took the $N$ elements (in this case, 11) from a given set of concepts and selected one as an anchor to which the other $N - 1$ elements had to be assigned or not assigned according to an individually given similarity criterion. This procedure (while retaining the original anchor) was repeated with each new positive or negative subset until either only indivisible sets with one object remained, or an individually selected break-off criterion was attained at which the set should not be broken down further.

As each concept took the position of anchor once, we obtained a total of $N (11)$ decision trees whose nodes contained the subsets produced and whose edges had a negative or positive sign, depending on whether the elements were assigned or not assigned to the anchor concept. A measure of the distance between the successively assigned or not assigned elements and the anchor concept (on an interval scale level) was obtained (see Schack, 2001).

2. The structured relations between the $N$ concepts were obtained by compiling a distance matrix through the scaling procedure presented above and subjecting it to a hierarchic cluster analysis.

3. The dimensioning of the set of concepts was performed with factor analysis and a special cluster-oriented rotation procedure. This factor analysis delivered the features (factors) and their weights (factor loadings) according to which the cluster formation (structuring) proceeded in each single case.

4. As cluster solutions could differ interindividually (as a function of expertise) and intraindividually (as a function of learning), it was necessary to subject them to an invariance analysis. This was based on a specially defined structural invariance measure $A$ (Lander & Lange, 1992; Schack, 2001, 2002). When two structures possessed a higher value than the invariance measure $A_0 = .68$, they were held to be invariant.

We would like to expand on this method and go into further detail using the following tennis study. The expert group consisted of eleven 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 eleven males (mean age = 26 ± 4.8 years) who were players in lower German leagues (district leagues), without being listed in the German men's rankings. For preparation, the participants were made familiar with the above BACs by way of pictures with a verbal BAC name as a printed heading. During the entire experiment, these pictures were continuously positioned in front of the respective participant. In order to determine subjective distances between the BACs, the participants performed the following split procedure, as the first step of SDA-M. On a computer screen, one selected BAC was continuously presented as an anchoring unit in red-colored written language. In addition, the rest of the BACs were presented in yellow-colored written language, as a randomly ordered list. The participant judged for each of these yellow-colored additional BACs, whether they were “functionally related while performing the movement” to the anchoring red-colored BAC or not. In this way two subsets were created which were submitted to the same procedure, and so on, until the referee.
decided not to do any further splits. The results of the hierarchical cluster analysis are shown in Figures 3a and 3b.

**Figure 3** Dendrograms for the subjective distances of Basic Action Concepts (BACs), resulting from the hierarchical cluster analysis of the means of the three groups, namely experts, low level players, and non-players. [The chosen significance level in all analyses was always $p = .05$. On the right side of each dendrogram is a scale displaying the extent of the distances between the single BACs in the subjects' long-term memory, measured in Euclidean distances. The smaller the numbers are, the smaller are the distances of the BACs in long-term memory.]

In experts, the cognitive structure comes close to the functional structure of the tennis serve. The three functional phases, namely the pre-activation phase, the strike phase, and the final swing phase, are clearly separated in the dendrograms, in the form of tree-like structured clusters. In experts (Figure 3a), the BACs seem to be grouped in memory according to generic terms which conform to the solution of special movement problems. The results obtained for the low level group look rather different (see Figure 3b). Here, the clustering of the BACs mirrors less well the biomechanically defined phases. In addition, the BACs are less clearly grouped, with no close neighbourhoods, and the partial clusters are usually below the chosen significance level. In individual low level players, significantly separated sub-clusters can also be seen, though not so frequently and clearly as in experts. The biomechanically defined phases, though regularly shining through, are not so properly and uniformly matched. Having gained such information about memory structures, the coach gets a better idea about how to adjust his or her instructions to the individual athlete.

Special computer programs were developed to apply this method so that such experiments could be carried out within a reasonable time (10-15 min; the programs are available from the first author on request). It is possible to measure such structures in athletes directly in the training process with the help of simple laptop computers. On the basis of these and other methods (Schack, 2002), it is possible to economically determine movement knowledge in technical preparation, and to compare persons or groups in terms of the structure of their knowledge. At the same time, such an experimental diagnosis delivers important information for deriving intervention procedures designed to improve technical performance (Blaser, Stucke, Narciss, & Komdle, 2000; Schack, 2002; Schack & Heinen, 2000).
TOWARDS AN INTEGRATIVE PERSPECTIVE IN TECHNICAL PREPARATION

It is already apparent in the comments concerning definitional issues of technical preparation that technical preparation cannot be reduced to the biomechanical analysis of technical output in training or competition. A model description of the construction of movement techniques was set in contrast to this incomplete theoretical idea of technical preparation. This model description shows how different components and levels of movement functionally interact to achieve a particular output. Accordingly, technique training is about the integration and the structuring of input-, throughput-, and output-modules (components) across different levels. These components, for instance, organize anticipation, perception, representation, and motor execution. Thus, depending on the level of expertise and degree of automation, technique training should begin at precisely defined levels and representation structures. Starting with such a model, an integrative perspective of technical preparation is indicated. This perspective is based on a connection of biomechanical accesses to the analysis of a movement task, of kinematic analyses, and the measurement and manipulation of psychological factors in technique training (Schack, 2003b).

According to this perspective, biomechanical movement analysis occurs as one step. This functional movement analysis is meant to more exactly characterize the movement task. At this point the movement is split up into different phases. These phases are more precisely defined regarding their function in the motion sequence, and subdivided into different functional phases (Gohner, 1979; Leuchte, 2004; Rieling, Leirich, & Hess, 1967; Schack, 2004b). Therein, the arrangement of the functional phases is organized according to the movement problems that are to be solved. Rieling et al. (1967), for example, divided the movement into an initial phase, a bridge phase, a main phase, and a final phase (see Leuchte, 2004). The application of this procedure is illustrated using the "end over" in sailing/surfing. Besides this functional movement analysis, kinematic analyses of the actual movement representation are also essential for technical preparation (see the comments on apparatus gymnastics, Schack, 2003b).

As the production of stable and optimal coordination modes represents a central goal of technique training, these biomechanical analyses of the structure of a technique constitute a substantial center of reference for the optimization of psychological and coordinative factors in technical preparation. However, besides these biomechanical analyses, experimental analyses regarding the structure of technique representations are also of central importance (see the previous paragraph). Based on the model imagery concerning the construction of movement techniques, movements are controlled through such representations (level of mental representation). An equally meaningful role must, for example, be attributed to the registration and optimization of strategies for voluntary motor control (such as attention strategies) on the level of mental control. Hence, technical preparation should be based on a perspective which integrates analyses and technologies from different disciplines. The presented model concerning the construction of movement techniques constitutes the crucial pattern for the integration of such information.
STARTING POINTS FOR MENTAL FORMS OF TECHNICAL PREPARATION

With reference to the model presented to illustrate the construction of movement techniques, mental training designs can be systematically assigned to technical preparation as well. Starting from the stage of mental control, all forms of mental training that are concerned with voluntary strategies are relevant. This includes strategies which aim at an optimization of thoughts during performance (Lidor, Tennant, & Singer, 1996; Singer, 1985, 1988; Singer et al., 1993, 1994), those directed at focusing attention (Abernethy, 1993; Wulf & Prinz, 2001), or those strategies that generally target an optimization of selfmanagement (Meichenbaum, 1979; Schack, 1997). Singer (1985), for instance, developed a specific five-step approach meant to optimize learning processes on different levels of expertise. These five steps deal with reading, imaging, focusing, executing, and evaluating movement techniques. This approach combines awareness- and non-awareness-strategies. Depending on the level of expertise, awareness is allocated to each of these five steps to a different extent, the non-awareness strategy being prioritized. Such techniques are crucial for the acquisition and the stabilization of coordination modes. They become particularly relevant if a technique has previously been acquired, and thus are especially important in technical application training and technical supplementary training.

The establishment of routines (Schack et al., 2005) represents a form of training that should be learned within the bounds of technical supplementary training, but becomes eminently important for technical application training - and particularly for competition - at higher levels of expertise. Routines play a critical role in athletes’ preparation for competition and have been shown to be effective pre-competition, during the competition, and post-competition (Boutcher, 1990; Cohn, 1990; Schack, 1997). Most coaches and athletes recognize the value of competitive routines, but they are often unaware of the importance of routines in training. Athletes who develop routines for all aspects of their athletic experience, and adapt them to the specific settings and situations in which they perform, give themselves the best chance of success. Routines form the physical, psychological, and environmental foundation in which technical skills, physical conditioning, and mental skills can be optimally developed in training and used in competition. Between-performance (for sports that involve a series of short performances, such as tennis, golf, and baseball) enable athletes to maintain a high level of performance consistency throughout a competition. Post-competition routines allow athletes to evaluate their performances, learn important lessons from the competition, and use that information to prepare for future training and competitions. When routines are acquired, the levels of mental control and mental representations are heavily involved. In the subsequent training process, the levels of sensorimotor control and sensorimotor representations are increasingly involved before these two levels finally take complete control in the automation stage.

In acquisition and application of stable coordination modes in technical performance, mental representation plays a central role. On this level, the structure of a movement is constituted beyond all learning stages (see Figure 2). Imagery training strongly builds on this level. Movement imageries are formed in structural relation with movement representations in long-term memory (see Schack, 2002). Therefore, it is useful to utilize
information about the structure of the movement representation in long-term memory if the goal is an individualized imagery training. For this purpose, we have developed a specific Mental Training based on Mental Representation (MTMR) (Schack & Heinen, 2000).

Furthermore, information about the structure of movement representations is of central importance regarding the acquisition of suitable modes of coordination as well as their stabilization. The structure of movement representations constitutes a functional component of technical performance and, in addition, is meaningful for coach-athlete interactions in technical preparation. As we know from numerous studies, coaches (as experts) and athletes (beginners) often do not use the same information at a specific stage of motor learning of an athlete, namely, the athlete develops an "intuitive" feeling for the water, a "feeling for movement," etc., and the originally applied instructions are no longer valid for the cognitive structure of the learning athlete. Such divergences within the coach-athlete interaction represent a specific reason to obtain a closer insight into the construction and change of cognitive structures in technical preparation and technical performance. As to this domain, examples are provided in the two following sections. Therein, it becomes apparent how technical preparation can be pursued from an integrative perspective.

INDIVIDUAL SPORTS
SPECIAL ASPECTS/INTRODUCTION

In individual sports, technical preparation plays an essential role in the training process as well as in competition. In comparison with team sports, the relevance of tactical and social factors within the team is limited at first. Oftentimes, especially in individual sports, conceptions of ideal technique executions (desired values) exist. However, in areas of higher performance, such desired conceptions are only of limited value. For this reason the aim is to display how starting points for an individualized technique training can be derived using the presented methods. Hereto, movements were selected from sailing-surfing and gymnastics. The comparison of these two sports is quite interesting. While well-known techniques have existed in gymnastics for several decades, elite athletes in sailing-surfing sometimes depend on the creation of completely new movement techniques.

EXTREME SPORTS: THE FRONT LOOP IN WINDSURFING

Technically sophisticated and novel techniques, for example rotational movements in windsurfing, have proven to be particularly interesting for technical preparation. Until 1986, the possibility of performing an end over in windsurfing (see Figure 4) was only speculated upon. Up to that time, it hadn't been clear how the impulse for forward rotation could be generated out of an ongoing forward motion. In 1985, Cantagalli became the first to perform a forward rotation (which he called a "Cheese Roll") in international competition. This evoked a boom of experimentation with highly complex movement actions in many
The front-loop represents a mixture of a rotation around the horizontal axis and a rotation around the longitudinal axis. We are dealing with a movement that represents a technical challenge for both highly-skilled hobby-windsurfers and competitive windsurfing professionals. This evaluation is supported by the fact that there are windsurfers with high technical abilities who are unable to perform jumps involving forward rotations. For the execution of this forward rotation, the following subproblems of the movement task have to be solved:

1. The athlete has to execute a sufficiently high jump from the water surface (optimally 5-8 m, but at least as high as the mast) (energizing problem).
2. At the peak of the jump, the athlete has to introduce the rotation. The impulse starts at the sail's pressure point, which, after take-off from the water surface, is located above the barycenter of the complete system. At this point, an enormous mass moment of inertia has to be overcome (impulse-introduction problem).
3. During the forward rotation, the windsurfing board system has to be stabilized (stabilization problem).
4. During the entire movement, numerous orientation problems resulting from the rotation have to be solved. 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).
Various movement phases can be distinguished in biomechanical terms. These movement phases can be subdivided into main phases and supportive phases. This subdivision becomes apparent in Figure 4.

BACs were ascertained for the presented functional phases, which contained substantial means 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 this figure. The concepts relevant for the movement were gained in a process involving several stages. First, a group of athletes consisting of experts (n = 8) and beginners (n = 7) gave spontaneous descriptions of the movement (front-loop in windsurfing). Subsequently, the subjects were interviewed individually regarding the BACs from their point of view. At this point, it became apparent that BACs were not only verbally labeled, but could also be demonstrated as a specific movement pattern (see Figure 5). Following an active execution of the movement, the formerly gained results were complemented — respectively corrected — using video-based self-confrontation. Later, complementing allocation experiments were conducted (Schack, 2002).

The acquired BACs for the frontal loop are: (1) high-low-high, (2) take-off, (3) opening the sail, (4) moving center of gravity to the front, (5) introduction of rotation, (6) becoming compact, (7) shifting the sail, and (8) turning the head.

A total number of 40 test subjects (experts and novices) participated in a special study for the preparation of new forms of technical preparation: n = 20 experts (all male); mean age = 28.8 years; engaged in windsurfing for 15.8 years on average; execution of front-loop on average for 9.4. This group of people consisted of American, French, and German athletes who, at that point, were counted among the world elite in windsurfing. A number of these athletes rank among the pioneers of windsurfing and have been involved in the movement from its beginning. All athletes were participants in international competition (World Cup, Grand Prix, etc.) and professional windsurfers. They were able to perform the front-loop reliably and variably in a competitive setting (some as a double frontal loop). They trained about 30 weeks annually. The fixation of expert status was oriented according to an ability status of at least 7 years duration of front-loop execution on a competitive level.

In the same manner, the group of novices (n = 20, 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) consisted predominantly of German and American athletes. These athletes trained
approximately 23 weeks annually. They participated in national and international competitions, yet without rankings worthy of being mentioned and without being able to perform the front-loop under competitive circumstances. Overall, the (potential) course of development for this group was comparable to the expert group. Hence, we are talking about persons who have the capability to reach the level of experts, but haven't gotten there yet. For the underlying study it was mainly of interest that the novices, as compared to the experts, mastered the technical execution of the front-loop far less reliably and variably. The sovereign execution of the movement (according to expert testimony) greatly depends on the experience in windsurfing and on the repeated practical performance of the movement under various conditions. The minimum condition for acceptance into the novice-group was that the subjects had performed that front-loop at least twice (according to their own testimony).

The results of this study are illustrated in the following figures. For this illustration, a is constantly set at 5%; this equals a dkrit value of 3.51.

Figure 6 displays the group-structure of the experts (n = 20) as the result of cluster analysis in the form of a dendrogram and contends the factor matrix arranged according to clusters.

Cluster analysis provides three clusters. The ascertained structures of mental movement representation in the expert group show a remarkable affinity to the biomechanical functional structure of the movement. As can be seen in Figure 6 the functional structure of the movement could be divided into several phases. Take-off 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 (take-off, preparation of rotation, rotation) are spatially separate and temporally sequentially organized. We are assuming that they serve as means to the solution of specific subproblems (energizing, introduction of impulse, rotation).

Figure 7 illustrates the cluster solution of the novice group (n = 20).
Figure 7  
Results of the hierarchical cluster analysis of Basic Action Concepts (BACs) of the front-loop in the novice group (n = 20; α = 5 %; d, α = 3.51).

It is characteristic for these cluster solutions that the elements have a weak structural link. The BACs are located slightly above the critical distance (d, α = 3.51). Therefore, no structure can be proven for the whole group. Obviously, the technique-related representational structures are too weak at this point. For technical preparation, especially claims regarding movement, representations in individual cases are interesting.

When comparing the dendrogram of the novice with that of the expert group, a significant difference in the clusters becomes obvious. While the cluster solution of the expert-group follows a functionally-based phase structure of the movement, a comparable structure cannot be found in the novice. As for the novice, the elements are arranged differently and neither a phase-related clustering nor a temporal-sequential structure is noticed. Furthermore, inexpedient mental structures are apparent. Subject 4 (Figure 8) combines elements from different movement phases. As an example, this results in a

Figure 8  
An individual novice’s solution (subject 4) in the learning stage of rough coordination as the result of hierarchical cluster analysis. [The circular mark denotes the link between two elements that is obviously based on surface features. Explanations in the text (α = 5 %; dkra = 3.51)]
cluster, which consists of elements 5 (rotation) and 8 (head turn). Both elements of the
cluster represent rotary motions, yet, regarding functional aspects, have nothing in
common. While element 5 plays an important part in the introduction of the rotation,
element 8 completes it. Obviously, surface features - and no functional features - were
consulted for classification of the elements. The unification of these elements on the
representational level is oftentimes linked with typical movement errors on this level of
motor learning (rough coordination). In this context, novices often forget to complete the
movement with a hand turn, which usually leads to dangerous falls.

In this study, we were able to prove the relation of cognitive representation and
performance in a special movement-technique. It is shown that the cognitive structure
of persons with a high ability to perform is more differentiated and more strongly
function-oriented than is the case with beginners. Experts obviously are better able to
apply their knowledge practically to aim for optimal execution of the movement.
Furthermore, statements concerning cognitive structures are given, which are of
immediate relevance for training processes. Based on these statements the coach is better
able to decide the cognitive context which athletes can understand and work on. This
statement is particularly relevant for such movements which have to be carried out under
extreme time pressure and which assumedly make use of their non-declarative
knowledge.

Such analyses concerning representational structures and biomechanical structures of
a movement make it possible to derive consequences for technical preparation. Thus, it
becomes apparent in which phase of the movement respective representational
problems are located. A significant consequence for technical preparation is to train
precisely this motion sequence. For this aim, a specific way of teaching was developed
(Garzke, 2001; Schack & Garzke, 2002).

Herein, the first step (see Figure 9) consists of the imitation of the whole movement.
Firstly, the judo-somersault is perfectly suitable to train the frontal direction of rotation
and motion. By executing this movement, the structure of the front-loop can be trained

Figure 9 Technical preparation using movement execution in the front-loop; the whole movement is trained
as well as specific movement phases (Step 1).
and stabilized as a first step. Further focal points in this exercise are the acquirement of coordination and rhythm during rotation. Here, especially those movement components are executed which prove to be poorly structured in representations. The person whose representational structure is illustrated in Figure 9 has to focus his or her training particularly on the rotation phase. Therefore it is crucial that the athlete feels what the optimum movement structure "feels like." This way it can be felt that turning the head is not immediately connected with the rotational impulse. For the person who has difficulties with the execution it thus becomes possible to integrate the intermediate movements becoming compact and shifting the sail into the movement.

A substantial next step is the execution of the judo-somersault with the rigging. This way the movement structure can be further improved. By also incorporating the rigging, the practiced movement becomes more similar to the targeted movement on the water. Again, this method serves the purpose of working on the tactile movement effects. The athlete is meant to achieve further improvement regarding the movement structure (see Figure 10).

Figure 10 Judo-somersault with rig (Step 2).

The next step of technical preparation is to perform the exercise with a wooden board and rig (see Figures 11 and 12). This exercise causes the center of gravity to increasingly improve into the direction of the correct movement execution in the water.

The particular movement elements that can be trained are those which have proven to be problematic in the representational structure. From this suboptimal movement structure, the athlete is supposed to move towards an optimal movement structure. This way, the execution of the movement can be trained, for instance under special surveillance of
Figures 11, 12, 13
Training of specific key-points
of the movement with rig
and wooden board (Step 3).

shifting the center of gravity to the front (Figure 11), grabbing the sail close (Figure 12), or
becoming compact (Figure 13).

When the movement structure has been
acquired up to this point of technical
preparation, we suggest that the SDA-M method
be applied again in order to reveal the athlete's
representation structure. Conclusions can be
derived from this analysis for deciding on
further steps of technical preparation. At this
point, the representation structure should be close to the expert's structure, at least
regarding its basic organization (see Figure 14). If major
problems are still apparent in the representation structure, we recommend moving back in
technique execution and movement representation to step 2 or even step 1, depending on
the extent of the problem. If movement structure and representation structure prove to be
stable, we can proceed to step 4 (see Figure 15). Here, the movement is
executed in a dune, with the wind as an additional factor. This exercise aims at
stabilization of the movement structure. In particular, utilizing the wind enables the athlete
to have the basic technique available in increasing variability. The athlete now has to
apply the acquired
basic technique under varying environmental circumstances as a means of securing a stable movement. In this step of technical preparation, it is crucial to learn about the functional meaning of the head as the leading instance within the movement. Athletes who do not turn their head over the distal end of their shoulder will land on their back as a result of a lack of rotational impulse. Athletes who turn their head towards their rear neck during initialization of the movement will stop rotating and crash onto the water surface. On the shore, the 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.

Figure 14 Wooden board with rig, closeup view (see Garzke, 1998).

Figure 15 Exercises performed under the influence of wind (Step 4).

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. Similarly, this is only about 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 the direct practice of the front-loop. After a certain practice phase, or if problems show up right after beginning the exercise, we again incorporate the SDA-M method. The representation structures can thus be measured and evaluated.

As made obvious in this representative example of individual sports, the acquisition of representation structures can vastly contribute to the optimization of technique training. As the measurement only takes approximately 15 min and results of the analysis are immediately available, many opportunities arise for technical preparation.

A further step of technical preparation is to conceptualize a mental training that begins with the representational structure of the athlete. In such a mental training based on mental representation, the individual dispositions and concerns of the athlete can be respected.

TECHNICAL SPORTS: GYMNASTICS

The account concerning gymnastics will particularly illustrate the integrative perspective of technical preparation. Here, we will investigate once more how mental representation and
kinematic parameters can be related to one another. The essential question is how mental representation and movement execution are linked.

MEASURING REPRESENTATION STRUCTURES

In the first step, mental representations were measured in the forward somersault with a full twist. The results of the hierarchical cluster analysis shown in Figure 16 are characteristic of gymnasts who are able to perform a maximum number of half-twists in a layout somersault (novices). With an increasing level of expertise the cognitive structure changes, and comes even closer to a biomechanical functional structure. In both figures we find that some movement phases are separate from each other and are used to solve specific movement problems (e.g., generating energy, initiating rotation). A detailed analysis shows, for instance, that the BAC muscular control of leg joints is connected with the free flight for a novice (Figure 16). In an expert structure of motor representation (see Figure 17), the muscular control of his leg joints is connected with the take-off phase when performing the somersault. Therefore, the gymnast is able to perform a higher flight with a greater amount of angular momentum. In such studies we learned, for

![Figure 16](image)

**Figure 16** Dendrogram resulting from the hierarchical cluster analysis of basic action concepts (BACs) in the forward somersault. [The vertically aligned words denote the BACs. The horizontal numbers shows the Euclidean distances of the BACs in LTM in a normalized scale. The dendrogram shows the cluster solutions for gymnasts (novices) who are able to perform a maximum amount of 1/2 twist in a layout somersault (n = 6).]
example, that the occurrence of shifting and focusing of attention according to the muscular stiffening of the leg joints (during the learning process) is increased with a higher level of expertise.

**MEASURING KINEMATIC PARAMETERS (BIOMECHANICAL ANALYSIS)**

In order to perform a kinematic analysis, the movements were recorded with two cameras. Movement kinematics were analysed using a computer-based 3D-analysis software (AViP-System; Heinen, 2001). The subjects were asked to perform somersault flights on the trampoline. The amount of twists increased every sixth jump until the individual maximum amount was reached. Only the successful jumps were analysed, using the AViP-method.

When analyzing the movement kinematics, it may be helpful to look at the time of flight and the time-structure of the movement right from the beginning. Table 2 shows the data for the flight time and the time structure of the twisting somersaults.

Take-off was set at Os and parameters of the time structure (initiating twist and stopping twist) were normalized to the time of flight. With a higher level of expertise (higher amount
Table 2 Time of Flight and Time Structure of the Twisting Somersaults. [Time of flight is measured in seconds (± SD) and the parameters of the time structure are normalized to the time of flight (take off - 0% time; touch down - 100% time).]

<table>
<thead>
<tr>
<th>Number of twist(s)</th>
<th>Time of flight [s]</th>
<th>Time structure [% time]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>initiating twist</td>
<td>stopping twist</td>
</tr>
<tr>
<td>½ twist</td>
<td>0.91 ± 0.06</td>
<td>10.29 ± 4.77</td>
</tr>
<tr>
<td>1/1 twist</td>
<td>0.93 ± 0.09</td>
<td>7.40 ± 3.20</td>
</tr>
<tr>
<td>1½ twists</td>
<td>1.02 ± 0.06</td>
<td>6.01 ± 2.51</td>
</tr>
<tr>
<td>2 twists</td>
<td>1.02 ± 0.05</td>
<td>4.27 ± 1.11</td>
</tr>
<tr>
<td>2½ twists</td>
<td>1.07 ± 0.06</td>
<td>3.74 ± 0.61</td>
</tr>
</tbody>
</table>

of twists) the moment of initiating the twist comes closer to the take-off and the moment of stopping the twist comes closer to the touch-down. The transition between initiating the twist by an asymmetrical arm/hip-movement and performing a contact twist may not be observable by the trainers' eyes because of the high movement velocity. Even stopping the twist close to the touch-down may result in stopping the twist when colliding with the ground. The trainer has to pay attention to the moment of initiating the twist and the moment when stopping it. Both moments should be during the free flight.

Table 3 shows the angular velocities according to the longitudinal and the lateral axis of the body and the tilting angle when performing the twisting somersaults.

Table 3 Angular Velocities According to the Longitudinal Axis of the Body (WLcAB) and the Lateral Axis of the Body (WLOAB) when Performing the Twisting Motion (γ describes the Tilting Angle.)

<table>
<thead>
<tr>
<th>Number of twist(s)</th>
<th>WLcAB [°/s]</th>
<th>WLOAB [°/s]</th>
<th>γ [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ twist</td>
<td>569.25 ± 101.77</td>
<td>308.73 ± 44.47</td>
<td>11.06 ± 3.50</td>
</tr>
<tr>
<td>1/1 twist</td>
<td>649.60 ± 77.61</td>
<td>297.92 ± 21.48</td>
<td>11.22 ± 3.03</td>
</tr>
<tr>
<td>1½ twists</td>
<td>900.35 ± 155.27</td>
<td>315.48 ± 38.53</td>
<td>12.45 ± 2.61</td>
</tr>
<tr>
<td>2 twists</td>
<td>965.20 ± 115.34</td>
<td>289.54 ± 16.17</td>
<td>14.14 ± 1.74</td>
</tr>
<tr>
<td>2½ twists</td>
<td>1012.50 ± 159.10</td>
<td>320.22 ± 37.90</td>
<td>14.70 ± 1.75</td>
</tr>
</tbody>
</table>

With a higher expertise level (higher amount of twists) we find an increase in the angular velocity according to the longitudinal axis of the body when performing twisting somersaults. The angular velocity according to the lateral axis of the body remains nearly the same. With an increase in twisting velocity we find an increase in the tilting angle. A larger tilting angle induces a greater twisting velocity.
RELATIONSHIP BETWEEN STRUCTURE OF MOTOR REPRESENTATION AND THE KINEMATIC STRUCTURE OF THE MOVEMENT

According to our ideas concerning the units of movement control, the whole movement is structured and controlled by way of cognitive-perceptual representations. In this perspective movements are organized by means of event-representations. Therefore, the hierarchical structure of movement representations seems to be close to the kinematic events of the movement and far from muscle activation patterns. While investigating the motor representations of the somersault, we learned that this structure is topological in nature, meaning that the structure involves information concerning the space and time of the movement. We also learned about the relationship between the maximum amount of twists and the structure of motor representation. After measuring kinematic parameters we are able to directly study the relationship between structure of motor representation and kinematic parameters.

First, the kinematic parameters and the structure of motor representation of every subject were evaluated. We have seen some results in the previous sections; then the data of every test were related to each other (see Figure 18). Statements concerning the structure of motor representation were gained from the hierarchical cluster analyses of the SDA-M method (Euclidian distance matrix). The relevant parameters here are Euclidian distances between the units of representation (BACs). Now we are interested in learning about the correlation of measured kinematics and the Euclidian distances between relevant BACs. Since we believe that motor representation is of functional significance for movement control, we assume a correlation between the structure of BACs and the structure of movement.

Figure 18 Design and methodological approaches of our study. (After measuring kinematic parameters and the structure of motor representation separately we are now able to combine the results by means of special forms of data analysis.)

When connecting these two kinds of data, significant correlations between important kinematic parameters (time structure, leg-trunk-angle, tilt-angle, angular velocities, etc.) and structural parameters of the motor representations are found. Figure 19 shows one example of the relation between a kinematic parameter and the Euclidian distance.
between two BACs. These two chosen BACs, twisting arms and hip and extending hip, are of functional significance for the initiation of the twisting motion. We find a negative correlation \((r=-.97; p<.00)\) between the angular velocity according to the longitudinal axis of the body when performing the twisting motion and the Euclidean distance of these two BACs.

These results indicate a direct translation of the Euclidean distance between the BACs twist by arms/hip and extended hip into movement-parameter (angular-velocities). The greater a Euclidean distance, the lesser the angular velocity. A gymnast whose motor representation shows big Euclidean distances between the described BACs is not able to produce a large number of twists. This is interesting, because the two BACs are located in the free-flight phase, where the athlete has to initiate the twist. Hence, we come to the conclusion that during the learning process not only the structure of movement concerning the amount of twists changes, but the structure of representation changes too. In the reported case the Euclidean distances may become smaller and the athlete increases his capability of performing and controlling the movement. Therefore, there might be a direct link between motor representation and biological organisation of movement control. From this point of view we do not need additional motor programs. More probably, motor representations are directly connected to a network of perceptual elements or representation, as described by Mester (2000) and in recent studies by Mechsner et al. (2001). According to this idea the whole movement is structured and controlled by way of these perceptual and conceptual representations.

Results from our study support this perspective. For instance, when correlating the BACs take-off and touch-down with the time of flight, we found a significant correlation \((p <.00)\). So even the time of flight seems to be mapped (implicit) in the structure of motor representations. Additionally, we found direct links between special body angles (for instance the angle between the thighs and the trunk during take-off) and the accessory parts of motor representations.
The investigated relationships between the structure of motor representations and the movement kinematics draw far-reaching conclusions. These results support the hypothesis that voluntary movements are planned, executed, and directly stored in memory by means of representations of their anticipated perceptual effects. In this view, representations create a link between the central goal and the biomechanical organization of the movement. For general statements concerning the organization of complex movements in different kinds of sport, further research is necessary.

TEAM SPORTS

In team sports, technical performance, in addition to a host of other factors such as tactics and team coherence, has a strong influence on a team’s overall performance. Yet, suitable action patterns - and therefore stably accessible technique execution - can still be viewed as crucial, basic conditions for performance in team sports. In this regard, technique training serves an important function. In a first step we will present ways to access technique training, implementing the method we developed for top-level volleyball. This is followed by a presentation of soccer.

VOLLEYBALL

We have chosen as an example a current study conducted in top-level volleyball. The selected movement task is the spike, which is also often called a "hit." Figure 20 presents the volleyball skill.

This movement task is of a structure which can be more closely defined using functional movement analysis (Engel & Schack, 2002; Schack, 2002). For each functionally located
movement phase, allocated representation units (BACs) were set (see http://www.spormed.de/area/proment/anc/anc.html). Table 4 presents the list of used BACs of the hit in volleyball.

**Table 4** Basic Action Concepts (BACs) of the Hit in Volleyball

First, we will illustrate the results using a single case (see Figure 21). Two players of the women’s youth National team will serve as an example for a discussion of different technique profiles in memory. The results are displayed as "dendrograms", which are based on hierarchical cluster analyses.

**Figure 21**
Technique profile of the "hitting skill" of player A in motor memory. [The numbers correspond to the numbering in the list of BACs mentioned above. Technique profile “spike” of an expert (ace spiker) from the German National team concerning formerly mentioned quantity of BACs (Distance measures: dmax = 3.5; dcrit = 3.3; a = 5%). The lower the value of a horizontal connection between the BACs (see set of values of Euclidean distance on the right), the lower the distance of the BACs in memory.]

Player A is an ace spiker. Her memory displays clearly structured movement representation (movement imagery) that is an almost ideal type. BACs 1-3 in connection with 4 and 5 constitute the phase of "approach and jump" in the memory of player A. Terms 6, 7, and 8 combine to make up the phase of "preparation for the hit," and terms 9, 10, and 11 represent the "execution of the hit." The truly interesting element at this point is the comparison with player B (see Figure 22).
She (player B) has been playing the identical position for several years, but has been having difficulties managing an optimal execution of the hit. In her own view, the cause of her difficulties was to be found in her insufficient jumping height. This explanation seemed unreasonable, though, because the measures of her jumping abilities provided excellent results. Her coaches observed difficulties in the backswing of her hitting arm prior to the hit. Our analysis makes a more precise definition of the possible problem (see Figure 22). The BACs making up the approach and jump reveal a structure of less clarity in player B (circled) as compared to player A. One BAC (1) was even allocated to a different phase (preparation of hit). Other than that, approach and jump is broken into two inefficient clusters (5-2; 4-3) while ideal-type clusters (1-3; 4-5) (see Figure 21) become visible in player A as far as biomechanical analyses are concerned.

Accordingly, this led to the conclusion that player B incorporated an inefficient sequence of impulses in approach and jump and that this caused her jumping height to be only suboptimal. This is the origin of the insufficient backswing of the hitting arm (as observed by the coach) and, finally, for the bad hit. As a consequence, technique training was changed, and a training was deducted which focused on an optimization of the sequence of impulses in approach and jump. Moreover, an individualized mental training (imagery training) was implemented which started from the individually acquired mental representations and integrated kinesthetic patterns (the impression of an ideal jump and a proper hit). This way, player B's hit could be improved significantly prior to the 2001 Women's Youth World Championships. She has subsequently managed to get on the roster of Germany's A-National Team.

Our studies in volleyball, and in other sports as well (Heinen, Schwaiger, & Schack, 2002; Schack, 2002; Schack & Heinen, 2000), have proven and underlined the functional meaning of a level of mental representations in motor learning. As a result, further steps for the optimization of motor learning are to be expected in this context. If both coaches and teachers are aware of their athletes'/students' mental movement representations, they will gain a better understanding of how to intervene in the learning process and optimally instruct and address their learners.
Another team sport in which studies regarding technical preparation have been conducted is soccer. Subsequently, we will present a study we engaged in to gain information about mental representations of the heading technique, which is illustrated in Figure 23.

Figure 23 Sequence of the heading technique in soccer.

In this study we measured the differences in mental representations of the header in an expert who currently plays in the Bundesliga (the top division in Germany), and a subject with a comparably lower expertise level who plays in the fourth division (Oberliga). The expert (Player 1) attended an average of eight practice sessions plus one game per week, whereas the player with a lower level of expertise (Player 2) usually practiced four times a week and participated in one game weekly. Both players were central defenders, a position for which a good heading technique is considered crucial. Moreover, they had very similar anthropometrical data (difference in height: 1 cm, "similar build"). However, observing the two players' repeated performance of an isolated heading drill, it appeared to us that Player 1 - despite not accomplishing greater jumping height - was able to execute the header much more explosively and give the ball a substantially higher pace than Player 2.

Subsequently, the two players were subjects of a study implementing the SDA-M-method. Similar to the previously presented study concerned with the spike in volleyball, allocated representation units (BACs) were set for each of the three functionally located movement phases. The BACs were derived from video analysis of headers executed by professional soccer players, as well as from movement descriptions included in relevant literature (Bauer, 1997; Bisanz & Gerisch, 2001).

Table 5 Basic Action Concepts (BACs) of the Header in Soccer

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<tr>
<td>1.</td>
<td>Stem-step</td>
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<td></td>
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<tr>
<td>2.</td>
<td>Bending knees and trunk</td>
<td></td>
<td></td>
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<tr>
<td>3.</td>
<td>Swinging arms forward</td>
<td></td>
<td></td>
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<tr>
<td>4.</td>
<td>Extending legs</td>
<td></td>
<td>(Run-Up/Jump)</td>
</tr>
<tr>
<td>5.</td>
<td>Upper body is arched back</td>
<td></td>
<td>(Preparation of Header)</td>
</tr>
<tr>
<td>6.</td>
<td>Legs swing back</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Drawing chin towards chest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Accelerating forehead towards the ball</td>
<td></td>
<td>(Execution of Header)</td>
</tr>
<tr>
<td>9.</td>
<td>Swinging arms back</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Forehead meets ball</td>
<td></td>
<td></td>
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<tr>
<td>11.</td>
<td>Bending the trunk</td>
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Table 5 presents a list of those movement phases (in parentheses on the right) and BACs that were used in this study:

To begin with, we will briefly discuss the results for Player 1 gained through the SDA-M method. A graphical display of these results as dendograms is presented in Figure 24.

The expert structure displayed for Player 1 reveals a well-organized mental representation of the header. The clusters of BACs in the dendrogram generally correspond well with the functionally ordered phases we proposed in Table 5, although the expert has allocated the BAC *Swinging arms forward* (3) to the phase Preparation of Header. However, due to the fact that strictly taken, the forward-swing of the arms takes place across the two phases of *Run-Up/Jump* and Preparation of Header, this does not detract from our assessment that Player 1's heading technique remains very close to the movement execution found in respective literature. In a similar fashion, the mental representation structure of Player 2 (see Figure 25), the player with a lower level of expertise, is fairly consistent with respect to the initially determined movement phases. Hence, we can also attest that he has a well-structured heading technique.

However, a slight but potentially crucial difference of Player 2's cluster formation in comparison with the results for Player 1 is to be found in the *Execution* of header-phase, in which especially the BACs Accelerating forehead towards the ball (8), *Swinging arms*
back (9), and Forehead meets ball (10) are organized in remarkably closer affinity in the expert's memory. This supports the impression of a discrepancy regarding the explosiveness of the two players' heading techniques that we had when observing their movement executions, which, in retrospect, had been visible as a less intense backswing of the arms and flexion of the trunk in Player 2.

When attempting to incorporate this newly acquired knowledge into a technique training to improve Player 2's heading technique, we recommended focusing on this latter movement phase. It was important for Player 2 to gain cognitive insight into the lack of explosiveness he revealed when executing the header. For this aim, implementing media for visual feedback might prove to be successful. Simply videotaping a sequence of Player 2's heading technique and subsequently contrasting it to an expert's technique should contribute to a better understanding of the discrepancy in explosiveness (if the two players happened to play on the same team, one could even use computer-based methods such as cross-fading procedures to further illustrate the differences).

Thereafter, we proposed an individualized technique training overemphasizing the sequence of impulses of the Executing the header-phase, namely BACs 8, 9, and 10. This training should first be pursued without the ball and later with the addition of the ball. Furthermore, mental training in the form of imagery training could be used as a further intervention method for Player 2 to acquire the proper kinesthetic pattern.

COMPUTER-BASED METHODS IN TECHNICAL PREPARATION

Figure 26 Video-cross-fading in downhill skiing competition for comparison of the skiers' lanes.

The development of digital video-techniques opens up a variety of new opportunities for technical preparation in sport (see, for example, the display presented in Figure 26). Besides the mere display of moving images, digital supplementing and analysis of video images can introduce these new perspectives.

1 The authors would like to thank Coach Daniel Niedzkowski for the substantial support he provided to the above part of this chapter. We are especially thankful that he contributed his wide-ranging experience in the field of soccer to further illustrate the practical dimension of technique training.
Such procedures can be used particularly well to reveal differences in speed, for instance in downhill skiing. Furthermore, the simultaneous display also shows differences in movement techniques. Through this means, key-points and errors in motion sequences can easily be emphasized and utilized as additional information in technique training.

1) Inserting movement paths adds to the video sequence. By utilizing tracking-procedures (see Intel 2001) which follow objects based on their structure and/or color information, movement paths of athletes or pieces of equipment can be recognized and drawn in the video image. Here, movement paths, which are not directly recognized or are extremely long, are made visible. Figure 27 displays the tracked lanes of two downhill skiers in connection with the cross-fading procedure.

2) With the help of mathematical models and simulated arithmetic, movements and movement paths can be created and visualized on the computer screen (Seifriz, 2001). Starting with tracked movement paths and kinematic analyses, optimized movement solutions can thus also be presented visually and compared with real movements. Figure 28 shows an image taken from an animation of an optimized lane on a slope created via GPS-measurement.

We have gone further into the question of how a modular measuring set can be constructed, which for the support of motor learning processes combines kinematic analysis of movement technique and analysis of mental parameters, and utilizes those in technique training. This enhanced movement representation analysis inventory (e-BRAIN; Schack & Heinen, 2002).

Module 1 of e-BRAIN is made up of the previously presented method for measuring mental movement representations. These data provide vital information for technique training, and highlight the mental framework of movement organization. On the other hand, the movement can be illustrated, for instance, through the use of biomechanical measurement procedures (Module 2). The parameters thus collected form a complex yet structured web of parameters. It is the aim of e-BRAIN to
acquire such parameter-webs not separately, but to establish a connective function between the mentioned pools of values (representation-related and biomechanical data), to use them as feedback in technique training, and to utilize them for simulations.

Figure 29 shows the measuring set build-up 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 of the analysis of movement kinematics which is used to report the movement via an animation and to simulate partial aspects of the movement (as in the context of technical errors) (on the right). As a consequence, e-BRAIN, for one, provides data regarding the athlete's movement organization (structure of movement representation, kinematic data, and linkage of both sets of data). Moreover, e-BRAIN also delivers extensive information that can be used as visual feedback.

**Figure 29** Split-screen presentation of e-BRAIN.

**CONCLUSION**

Based on new and integrative perspectives concerning technical preparation, this chapter introduced various tools that play an essential role in the work of sport psychologists. It is important to note that these tools are always applied in a specific training setting. In this setting, the sport psychologist can work directly with the athlete, for example by means of computer-based methods. However, he or she will also serve as a consultant to the coach. The underlying principle here should be that the person with the highest degree of expertise (coach or sport psychologist) becomes active in the ongoing training session or regarding the athlete's current problem. Thus, it is usually recommended that the sport psychologist advise the coach regarding the set-up of technique training. Experimental
analyses using the SDA-M are an example of how this purpose can be served. By means of such methods, it is possible to gain information about the cognitive background of specific difficulties during technique execution. The information thus gained can be utilized for deciding which elements or phases of the technique are to be improved and thus should be targeted through technical preparation.

On the contrary, the sport psychologist takes the active part when it comes to mental training. In this respect, he or she will discuss the structure of movement imagery with the athlete. For this aim, the psychologist can use the SDA-M-data already gained. He or she will also lead the execution of the actual mental training process.

Computer-based methods may be applied by both coaches and sport psychologists as a basis for their work. By means of such methods it is possible to give the athlete insight into different aspects of his or her movement execution and to illustrate the structure of the athlete's movement representation. Such methods are of high practical relevance when we aim at the development of more goal-oriented movement imagery and an improvement of technical performance.

Thus, the essential message of the chapter is that current experimental and media-based methods (tools) can support technique training on a high level. Central aspects regarding these efforts are the technical capabilities and health of the athlete. The presented methods and perspectives have been proven to supplement professional technical preparation, and yet they cannot replace it. Therefore, applying such methods demands a basic understanding of the training situation and a certain idea of the specific movement technique. New methods and approaches in technical preparation can systematically improve technical performance, especially where they enable a better understanding of practical events and the athlete's movement organization. In this respect, they should be regarded as substantial and effective components of our tool kit.
REFERENCES


