

INTERDISCIPLINARY ANALYSIS OF BIOMECHANICAL MOVEMENT PATTERNS AND MENTAL REPRESENTATIONS OF THE VOLLEYBALL SPIKE

Thomas Jaitner¹ and Thomas Schack²

¹TU Kaiserslautern, Kaiserslautern, Germany

²DSHS, Cologne, Germany

An approach for an integrative analysis of biomechanical and psychologic data is presented. Kinematic movement patterns as well as mental representation of the spike of male volleyball players have been studied to analyze structural interrelationships of cognitive and biomechanical measures. A high congruence of the results of cognitive and biomechanical analysis can be stated. Future research will focus on adaptations of mental representation and performance following practical and mental training, respectively.

KEY WORDS: technique analysis, mental representation, pattern analysis, kinematics, volleyball

INTRODUCTION: Biomechanics understand how movements are processed from an external view including the kinematics and dynamics. On the other hand, psychologists know much about the underlying internal (cognitive) mechanisms, e.g. the planning of voluntary movements. There was discussion during last years about the missing link between biomechanics and psychology or cognitive sciences especially for the analysis of complex gross motor movements (Pressing, 1998). Particularly, deficits on interdisciplinary research have been stated. An approach for a more integrative analysis is presented in this study. Biomechanical movement patterns as well as mental representation of the spike of male volleyball players have been studied to analyze structural interrelationships of cognitive and biomechanical measures.

A basic assumption of the analysis of perceptual-cognitive motor representations is that conceptual frameworks with basic action concepts (BAC) or "key points" are the relevant reference structures functional in complex movement control. These BAC can be considered as elementary concepts of complex movements which are characterized by functional and perceptual features (Schack, 2001). In experts, these frameworks are expected as economically organized, prototypical, long-term memory structures which are well adapted to the biomechanical demands of the movement. From the biomechanical view, a process oriented pattern recognition approach based on time-continuous data was chosen for two reasons: (1) The BAC's are considered to represent the sequences of single phases or parts of the movement. Biomechanical analysis are commonly based on parameters which describe the athlete's performance at given times or positions but lack information on how the movement has been processed in-between. More detailed knowledge about the whole movement sequence is available if time courses are analyzed. (2) Highly skilled athletes can be characterized by a high stability of their movement techniques, that means there are less differences between consecutive performances. Similarity measures are therefore appropriate to quantify the quality of movement techniques. The purpose of this study is to investigate if well-structured mental representations of movement techniques are related to high stabilities of the movement processing or, respectively, if partial deficits of mental representations correspond to a lower similarity of appropriate aspects of the movement processing.

METHODS: Subjects were male volleyball players of two national league teams. Their mental representations of the spike were analysed using a procedure, that consists of a hierarchical split procedure involving a multiple sorting task, cluster analysis and factor analysis (Schack, 2001). Spiking technique was described by 12 BAC's, that characterized the movement during approach, take off, preparation and hitting. Additionally, kinematic data of the spike were taken by two high speed video cameras (125 Hz) during competition. For each trial 3D coordinates of 10 body landmarks were determined from the beginning of the

take off to the first contact with the ball. The resultant time courses were smoothed with a recursive 4th order Butterworth filter. To describe the subject's movement, time courses of angles and angular velocities of the main joints were calculated by the time courses of the body markers. The distances between the time and amplitude normalized time courses were determined for all data sets according to (Schöllhorn, 1999). Distance matrices of various sets of variables were analyzed by cluster analysis using the single linkage algorithm.

RESULTS AND DISCUSSION: Figure1 and Figure2 show the results of the cluster analysis which are considered as mental representations of the spike for two subjects MP and BM, respectively, and will be discussed here as examples. For subjects MP, BAC's that represent the approach (1,2) and the take off (3,4,5) are clearly separated from BAC's that represent the preparation for as well as the hitting of the ball. A further subdivision of BAC's of the initial preparation can be seen. Because of the low distances between corresponding BAC's, the mental representation of this subject can be interpreted as well structured and nearly prototypical. Concerning the approach and the take off, the results for subjects BM are comparable. The other BAC's are clustered with high distances, which indicates less structure and therefore deficits in this part of the mental representation.

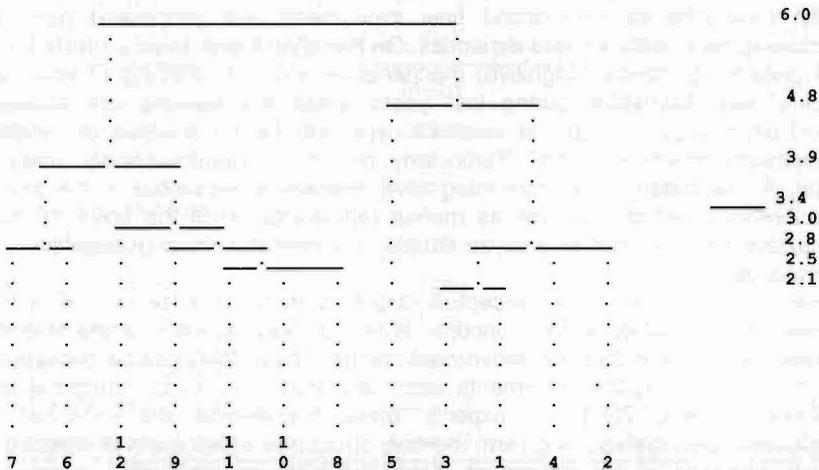


Figure 1 Mental representation of the volleyball spike for subject MP.

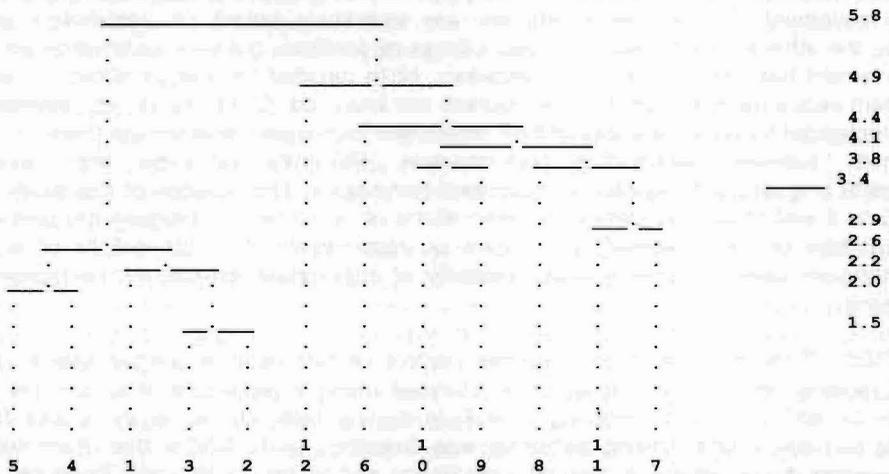


Figure 2 Mental representation of the volleyball spike for subject BM.

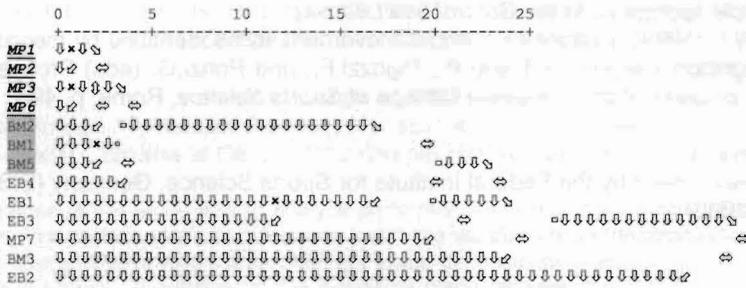


Figure 3 Cluster analysis of angles and angular velocities of the lower body.

The results of the kinematic analyses are shown in Figure 3 and Figure 4. If only angles and angular velocities of the lower body are considered (Figure. 3), the low distances between the trials indicate a high similarity of movement patterns of the spike for both subjects which can be interpreted as a high stability of the partial body movements. The trials BM3 and MP7 are performed as lob or soft top spin shots and for this reason clustered separately. Figure 4 shows differing results for the cluster analysis of upper body variables. While the trials of subject MP are still clustered with relative low distances in-between, the classification of the spiking trials of subject BM in different clusters is evident. This can be interpreted as lower stability of the upper body movements during the spike. High distances between the trials support this conclusion.

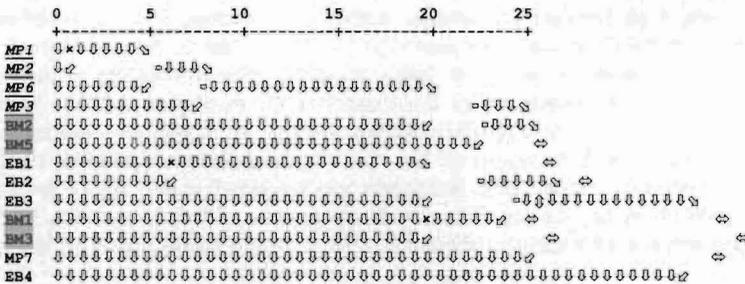


Figure 4 Cluster analysis of angles and angular velocities of the upper body.

A comparison with the mental representations shows a high congruence of cognitive and biomechanical analysis for both subjects. A well-structured representation of subject MP is accomplished because of the high stability of the spiking performance, whereas for subject BM deficits of the mental representation as well as a lower stability of partial movements can be observed. While those BAC's are less structured that represent partial movements mainly determined by the upper body and the arm, the assumption of a linear interrelationship to the movement sequence of the upper body seems promising. Overall, the results of this study support that experts can be characterized by a high level on performance in the movement processing as well as by a well-structured mental representation. With a more practical view on training, it is assumed that by mental training not only the mental representation of a movement technique can be improved but also an enhancement of particular aspects of the movement processing can be achieved. Effects of mental training on performance as well as effects of practical training on mental representation will be in focus of future research.

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