Bewegung und Sport
Psychologische Grundlagen und Wirkungen
Movement and Sport
Psychological Foundations and Effects

Proceedings of the
VIII European Congress of Sport Psychology 1991 in Köln
Volume 2
Edited by Jürgen R. Nitsch and Roland Seiler

Bewegungsregulation und motorisches Lernen
Motor Control and Motor Learning

VIII. EUROPÄISCHER KONGRESS FÜR SPORTPSYCHOLOGIE
VIIIth EUROPEAN CONGRESS OF SPORT PSYCHOLOGY
10.-15. September 1991 in Köln

Veranstalter · Organizer

Arbeitsgemeinschaft für Sportpsychologie in der Bundesrepublik Deutschland e.V. (asp)

im Auftrag der · on behalf of

Fédération Européenne de Psychologie des Sports et des Activitées Corporelles (FEPSAC)

in Zusammenarbeit mit · in cooperation with

Deutsche Sporthochschule Köln (DSHS)

Schirmherrschaft · Patronage

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Bewegung und Sport - Psychologische Grundlagen und Wirkungen
Movement and Sport - Psychological Foundations and Effects

Band · Volume 2

Bewegungsregulation und motorisches Lernen
Motor Control and Motor Learning

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Bewegung und Sport
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Bericht über den VIII. Europäischen Kongreß für Sportpsychologie
Proceedings of the VIIIth European Congress of Sport Psychology

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Motor Control and Motor Learning

herausgegeben von · edited by

Jürgen R. Nitsch und Roland Seiler

unter Mitarbeit von · in collaboration with

Roland Singer

ACADEMIA VERLAG SANKT AUGUSTIN

Die Deutsche Bibliothek – CIP-Einheitsaufnahme

Bewegung und Sport : psychologische Grundlagen und Wirkungen ; Bericht über den VIII. Europäischen Kongress für Sportpsychologie ; [10.-15. September 1991 in Köln] = Movement and sport / hrsg. von Jürgen R. Nitsch und Roland Seiler. [Veranst. Arbeitsgemeinschaft für Sportpsychologie in der Bundesrepublik Deutschland]. – Sankt Augustin : Academia-Verl.

ISBN 3-88345-587-3
NE: Nitsch, Jürgen R. [Hrsg.]; European Congress of Sport Psychology <8, 1991, Köln>; Arbeitsgemeinschaft für Sportpsychologie in der Bundesrepublik Deutschland; Movement and sport

Bd. 2. Bewegungsregulation und Motorisches Lernen / unter Mitarb. von Roland Singer. – 1994
ISBN 3-88345-584-9

1. Auflage 1994

Postfach 16 63, D–53734 Sankt Augustin
Printed in Germany

Umschlag: Lengowski und Partner, Köln
Typoskript: Florian Reimann
Herstellung: Richarz Publikations-Service GmbH, Sankt Augustin

Editorial

Seit einigen Jahren haben sich Psychologie und Sportpsychologie (wieder) zunehmend einem zentralen Aspekt des Sports und menschlicher Aktivität überhaupt zugewandt, nämlich der Bewegungsregulation und dem Bewegungslernen. Der hier vorliegende zweite Band des Berichts über den *VIII. Europäischen Kongreß für Sportpsychologie vom 10.-15. September 1991 in Köln* gibt in 45 Beiträgen von 85 Autoren aus 14 Ländern einen profunden Überblick über die psychologischen Grundlagen der Bewegungsregulation sowie über Grundkonzepte und Optimierungsmöglichkeiten des motorischen Lernens. Zahlreiche Beiträge beschäftigen sich darüber hinaus mit speziellen Fragen der internen Repräsentation, raumzeitlichen Aspekten des Bewegungsverhaltens, dem Zusammenhang von körperlicher Beanspruchung und Bewegungskoordination sowie individualtypischen Merkmalen des Bewegungsverhaltens. Die breit gestreute internationale Beteiligung ermöglicht nicht zuletzt die Orientierung über z.T. sehr unterschiedliche theoretische Positionen und Forschungstraditionen, mit denen wir uns auf dem Weg zu einem dringend erforderlichen integrativen Verständnis menschlichen Bewegungsverhaltens eingehend auseinandersetzen müssen.

Die in diesen Band aufgenommenen Beiträge wurden zwar in formaler Hinsicht nach Möglichkeit vereinheitlicht und z.T. auch inhaltlich zur Überarbeitung empfohlen, es wurden jedoch keine Beiträge zurückgewiesen. Manche Formulierungen mögen vielleicht nicht immer sprachlich ganz elegant erscheinen. Es sollte dann in Rechnung gestellt werden, daß viele AutorInnen durch die Festlegung auf zwei Kongreßsprachen (Deutsch und Englisch) nicht in ihrer Muttersprache schreiben konnten.

An der Erstellung dieses Bandes waren wiederum viele beteiligt. Besonderer Dank gilt den Mitgliedern des Wissenschaftlichen Komitees und den Mitglieder des Psychologischen Instituts der Deutschen Sporthochschule Köln, insbesondere Herrn Florian Reimann sowie Frau Gabriele Schieren.

Unmittelbar vor Drucklegung mußten wir erfahren, daß mit *Denis Glencross* einer der weltweit führenden Sportpsychologen, von dem auch einer der Hauptbeiträge dieses Bandes stammt, verstorben ist. Wir widmen ihm dieses Buch.

Jürgen R. Nitsch und Roland Seiler

Editorial

Since several years both psychology and sport psychology paid (again) increasing attention to a central aspect of sport and human activity in general, that is, motor control and motor learning. 45 contributions of 85 authors from 14 countries, included in this second volume of the Proceedings of the *VIIIth European Congress of Sport Psychology from 10-15 September 1991 in Cologne*, provide a profound survey of psychological fundamentals of motor control as well as of basic concepts and means to optimize motor learning. Additionally, numerous articles are concerned with special questions like internal representation, spatial and time aspects of motor behaviour, effects of physical load on coordination and typical individual characteristics of motor behaviour. Last but not least, the wide-spread international contributions provide orientation on partially very different theoretical positions and research traditions which we have subtly to deal with on the way towards an urgently needed integrative understanding of human motor behaviour.

All of the presentations included in this volume are adapted to the same formal schema as far as possible and some of them were also recommended for revision by the authors themselves. However, none of the submitted manuscripts was rejected. Perhaps some of the given statements may partially appear as not quite elegant in language. In those cases you should take into account that many authors had to write in a foreign language because of the limitation to only two congress languages (English and German).

Again, many people were involved in the preparation of this volume of the Proceedings. We want to give our special thanks to the members of the Scientific Committee as well as to the members of the Psychological Institute of the German Sport University Cologne, in particular to Florian Reimann and Gabriele Schieren.

Just before publishing, we got the sad news that *Denis Glencross*, one of the leading sport psychologists in the world who also contributed a main paper to this volume, has died. We dedicate this book to him.

Jürgen R. Nitsch and Roland Seiler

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Grundlagen der Bewegungsregulation

Fundamentals of Motor Control

THE ORGANIZATION OF MOTOR BEHAVIOUR: AN ACTION-THEORETICAL PERSPECTIVE

JÜRGEN R. NITSCH, GERMANY

Introduction

John McKoy is a proud man because he is souvereign of a world of about 50 sqm. He defends his claim by all means and doesn't care much about what happens around. Since 15 years he has dug for gold using the best equipment available, and sometimes he was even successful in discovering a few nuggets. But inspite of this small output, he is quite confident to make the great coup in the near future. Recently he was told that far away a new eldorado was found. Immediatly he prepared to follow the new rush. But years after changing the claim he learnt that he had left an oil field.

Are we all McKoys, working on small, strictly separated fields, looking for the wrong things and leaving everything behind us, when a new paradigm comes up?

I believe — and this is the schedule of this paper — that further progress in research on motor behaviour depends on (1) critically reviewing the present situation, (2) analyzing the implicite assumptions underlying our research activity, (3) reformulating the basic questions and, in particular, looking for an integrative perspective to solve these questions.

In my opinion, such an integrative concept can be derived most appropiately from an action-theoretical point of view. To say it in advance, action theory doesn't yet offer ready-made solutions, but it may help to find them.

The Present Situation of Research on Motor Behaviour - Critically Reviewed

Obviously, an impressive increase in experimental research on motor behaviour occurred in the last two decades, stimulated by cybernetic feedback models and computer technology on the one side and an increasing practical need in optimizing motor learning and motor control in various areas of movement and sport on the other side, e.g. in skill training in competitive sports as well as in industrial settings, or in rehabilitation and therapy of motor disorders.

Summarizing the state of the art, the following tendencies appear to be characteristic for the main stream.

Increasing Specialization and Particularization of Research

This trend led to more or less unrelated findings, concepts, terminologies and methods: "...plenty of isolated facts but little or no focus", as Kelso (1982, preface) resumed.

According to the experimental approach, small-ranged movements, very restricted in time and space as well as with respect to the situational constraints, are prototypical (Daugs, Mechling, Blischke & Olivier, 1991). The position of a single movement in a movement sequency, its 'history' relative to the individual learning process as well as its functional context with regard to underlying intentions are mostly neglected. At the best, such laboratory movements may have some ecological validity for quasi-experimental settings outside the laboratory as they may be found in a few highly restricted sport activities.

Furthermore, the particularization of the research field results in intra- and interdisciplinary dissociation or reductionism. In psychology, for example, learning theory doesn't care about motivation, in cognitve psychology there is no appropriate place for emotion. The integration recently offered within a "cognitive theory of emotion" seems to be nothing but pretending the existence of "wooden iron", according to a comment made by Dörner (1982, p. 1)

Biomechanical, neurophysiological and psychological approaches to motor behaviour and training are scarcely interlinked. Some terms — like 'coordination' or 'training' — are in common usage but have quite different meanings. Therefore, the primary problem of interdisiplinary cooperation seems to be not to communicate about central research topics, but metacommunication, that is, how to communicate in order to communicate about these issues.

Of course, the problem of disintegration is recognized by some investigators in the field of motor behaviour. However, from a historical point of view, the demand for integrative concepts as a result of the present situation of empirical research appears to be a little bit astonishing. A lot of similar statements as well as promising basic concepts can already be found in the early years of motor behaviour research. Recently, this was impressingly outlined by Ennenbach (1994), in particular reference to the writings of Buytendijk, Christian and von Weizsäcker. I have the impression that research on motor behaviour has a long-term history, but not a real tradition.

Predominance of the Information Processing Approach in Present Concepts of Motor Control

This approach can be illustrated by a model presented by Richard Schmidt in his very influential book on 'Motor Control and Learning' (1982).

The core of this model is, in the words of Schmidt (1982, p. 93), "to consider a number of distinct stages of processing, tentatively assuming that they are serial and nonoverlapping in time" (in the second edition of his book in 1988, Schmidt revised his position a little bit by adding the possibility of parallel processing).

This model, obviously based on a computer analogy related to computers of the present generation, is not only oversimplified, as Schmidt himself conceded. It is inappropriate in its central assumptions. In some special cases information processing may be initiated by an external stimulus in the sense of feeding a computer with data and commands. But in most of the cases under natural conditions it is initiated and modified by internal processes like motivation, emotion and intention, at least by a combination of both external and internal factors. In the area of motor research the evaluation is still valid which Simon already made in 1967: "Information processing theories, however, have generally been silent on the interaction of cognition with affect." (p. 29)

Furthermore, there is some strong evidence that information processing in human does not happen in a serial order of separate stages. 'Stimulus identification' is influenced by 'response selection' and 'response selection' by 'response programming', that is, they are not stages in a linear sequence but mutually dependent. Therefore, the information processing approach in a version like that mentioned above is a brief description of how a computer of the present generation operates and is at the best valid for specific computer-like processes in human beings. Remarkably, even computer scientists, as, for example, Strube (1986) pointed out, don't share the assumption that contemporary computers imitate the architecture of human information processing.

Finally, the information processing model is apparently a one-sided person-centred concept of movement behaviour placing person and environment at opposite banks of the river. This neglects an essential point of human behaviour organization, namely, that we do not only receive stimuli from the environment. We actively select and design the environment. That is, we indirectly produce the stimuli by ourselves which we must deal with in information processing.

Gap Between Experimental Research and Application

There is a great discrepancy between the amount of specific research findings and their relevance for practical demands. This point needs no further comment because it stresses the well-known problem of ecological validation of experimental results, connected with the problem of transfer of knowledge.

In summarizing these three points, there is no comprehensive concept which integrates discipline-specific approaches as well as different models of motor learning and motor control, thus providing a broad and differentiated basis which is urgently needed for application in various fields of sport. To prevent eventual misunderstandings, this does not mean that contemporary approaches to motor behaviour and the experimental strategy are considered to be inappropriate at all. In contrary, they are important components of the picture, but they don't provide the picture itself. Therefore, what we primarily need is not more research but another kind of research.

The first step to progress on this way is to critically analyze the implicite assumptions underlying our research activities.

Implicite Assumptions Underlying Research on Motor Behaviour — Do We Really Know What We Are Doing?

We all are familiar with the fact that theories should represent the characteristics of an object in question. However, we are often not aware of the fact that our knowledge is a construction which is influenced and restricted by our implicite concepts of human nature and environment, furthermore, by our language system which is not only a formal instrument for communication, but a result of experiences in the past, and, last but not least, by our modes of thinking.

The central point is that we sometimes formulate laws which prove not to be characteristic for the investigated object, but are inherent in our approach to the object. I will demonstrate this by some wide-spread stereotypes in research on motor behaviour, in particular the 'metaphor-for-reality stereotype', the 'homunculus stereotype', the 'library stereotype', the 'pyramid stereotype', the 'arrow-stereotype' and the 'either-or stereotype'.

The Metaphor-for-Reality Stereotype

Often we are not aware of the fact that our theoretical concepts and explanations may have quite a different epistemological status. They occur in three basic versions: Metaphors, models and theories in a narrow sense.

Theories are specific sets of interrelated statements covering a certain range of objects, events and interrelations. They are developed in the course of empirical research and need empirical validation.

Models are non-specific formal descriptions of functions or interrelations which we try to apply to various phenomena. If they prove to be not applicable to a certain problem, they nevertheless remain formally valid inspite of this, for example, mathematical models in psychology adopted from physics.

Metaphors are descriptions by analogy, for example the computer metaphor mentioned above. Most of our concepts in psychology appear to be more or less metaphorical (Gentner & Grudin, 1985).

Metaphorical descriptions are very important in all scientific disciplines for heuristic reasons. For example, the main problem in emotion theory is that we have no appropriate metaphor available since the days of the steam-boiler metaphor in ethology, psychoanalysis and some early drive concepts in behaviorism.

However, we must concede that metaphorical descriptions are as-if explanations and not statements on real processes.

The Homunculus Stereotype

The homunculus stereotype does not only appear in the 'Super-Ego, Ego and It' concept of psychoanalysis, but also in theories of motor control. The characteristics of observed behaviour are related to separate latent abilities which are considered to produce this behaviour.

For example, if we find that a person can hit a small target with high accuracy, we tend to attribute this observation to the ability of 'aiming'. If a specific behaviour pattern is shown, we relate it to a separate processor called 'information selection'. If a movement pattern is of high invariance, we assume a 'schema' which is considered to be responsible for this outcome, and we postulate a separate schema called 'recognition', to denote that responses are evaluated. That is, we derive the conclusion from observed characteristics that there must be a specific 'instance' or 'unit' or 'homunculus' which has produced these characteristics.

Theories of self-organization which were developed in chemistry (Ilya Prigogine), physics (Hermann Haken) and biology (Manfred Eigen) in the last two decades and recently tentatively applied to some aspects of motor behaviour, for example, by J.A.S. Kelso, provide strong evidence that order can occur without a preestablished steering unit (see, for example, Haken & Stadler, 1990, Kugler, 1988; Turvey, 1990).

The Library Stereotype

The library stereotype means that we usually consider the storage of knowledge as similar to those of books in a traditional library. Different contents are stored in separate books located at prescribed shelves in a fixed order. Nothing happens within the storage system, except material decay, until someone enters the library to use one of the books.

This 'one-information-one-location' principle seems to be not in line with recent research findings in neurophysiology. As Strube (1986) pointed out, there is some evidence that each neuronal unit contains a condensed package of the total information which is stored in the system.

The concept of 'dead', static or passive knowledge also needs revision. To explain both the high flexibility and the spontaneity of knowledge organization a concept of *'dynamic knowledge'* seems to be more appropriate. The central idea can be derived from the antigen-antibody reaction in biochemistry. Applying this analogy, the principle of dynamic knowledge organization can be illustrated in the following way (see Figure 1):

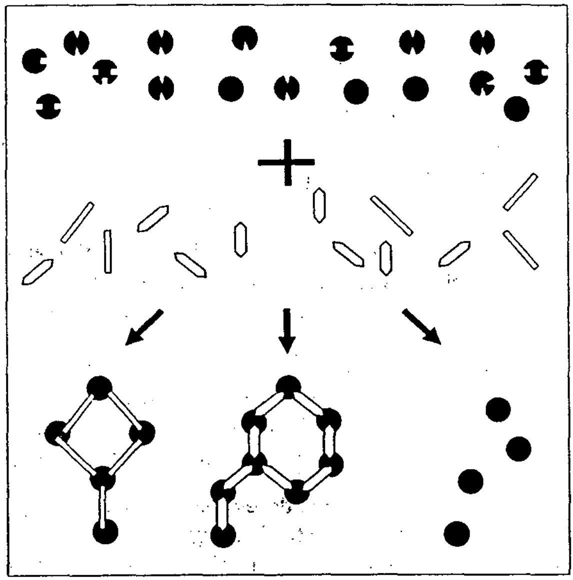

Figure 1. Illustration of dynamic knowledge organization.

(1) You see several circles symbolizing the information elements or facts.

(2) These elements or facts are or are not marked by specific notches symbolizing the syntactic, semantic and pragmatic rules which can be applied to connect these facts.

(3) The connection of these elements or facts depends on additional elements symbolizing spezific intentions. This includes that the same facts can be combined — or connect themselves in a self-organizational process — in a different way under different intentions.

According to this idea of dynamic knowledge organization, learning means to add, specify and combine facts, rules and intentions. In this sense, learning is not merely a process of knowledge expansion, but a marking process. That is, we must learn to use the knowledge which we already have.

The Pyramid Stereotype

The pyramid stereotype probably has its origin in hierarchically structured social systems and perhaps in human space perception, depending on experiences in upright walking on a stable ground. The core of this stereotype is that a single superior unit governs a number of subordinate units which determine the units of the next lower level, etc. This assumption appears in various concepts, e.g., in models of control levels, goal pyramids and hierachical organization of knowledge. However, there is some evidence that human behaviour is often not hierarchically organized in a strict sense. The following arguments may support this sceptical view.

"...human behavior appears to be responsive not to just one, but to a multiplicity of goals" as Simon (1967, p. 32) quoted. For example, we try to win the match, to impress the spectators and to maintain our self-identity at the same time.

Furthermore, behaviour is not only controlled in the top-down direction, but also by bottom-up influences as it is outlined in heterarchical concepts of behaviour organization (Turvey, 1977). Often we have no fixed goal when starting an action. In contrary, the final goal is developed in an iterative process during trials, for example in creative activity. In this case, characteristics of superior units at the same time determine and emerge from the activity of lower ones.

Finally, neurophysiological concepts of the brain structure as well as recent concepts in knowledge engineering suggest that network models can offer more appropriate solutions to our problem of behaviour and knowledge organization.

The Arrow Stereotype

The arrow stereotype means that we are used to analyze processes in a one-sided linear (mostly left-right) direction. This stereotype determines our explanations by the cause-effect schema as well as our concepts of serial organization of information processing and behaviour. Referring to this stereotype, necessarily circular dependency and retroactive effects, which are highly important in human behaviour organization, are left out of the focus.

The Either-Or Stereotype

The central point is the confusion of categories with aspects or perspectives. An object belongs to only one category but may be considered under various perspectives. Mistaking this, many theoretical assumptions are exclusive statements in the form of 'y *is* f(x)' (e.g., "motor behavior *is* controlled by schemas"), inspite of 'y is *also* (but not only) f(x)'.

This fact leads to serious consequences which we must deal with in the future. The real object of research on motor behaviour, i.e. human movement, is split up in separate aspects often overgeneralized and considered as exclusive alternatives (categories). Subsequently, a lot of debates on pseudo-problems rules the field, e.g. open loop vs. closed loop control, centralistic vs. peripheralistic focus, internal representations and schemas vs. affordances from the environment or attractors of self organizational processes, and, last but not least, quantitative vs. qualitiative approaches.

In summary, our theories are remarkably preoccupied by our modes of thinking. Such stereotypes are heuristically useful to a certain degree. In the long, however, they become a corset for further progress towards a more comprehensive and integrative perspective on behaviour organization.

The Action-Theoretical Approach - Essentials of an Integrative Perspective

The action-theoretical perspective is neither a really new one nor it is completed until now. It has some of its substantial roots in the topological psychology of Kurt Lewin, the theory of activity in the early Soviet psychology (e.g. Rubinstein and Leontjev) and in the well-known TOTE-model of Miller, Galanter and Pribram. In my opinion, it is not yet a closed concept, but a comprehensive and promising perspective to deal with psychological processes and phenomena.

What are the basic assumptions of the action-theoretical approach with regard to motor behaviour?

Motor Behaviour Is Behaviour-in-Situation

The central phenomenon referred to is not a bimanual single-angle movement in an artificial setting, but *human behaviour in every-day surroundings*. This implies that the focus is not primarily put on the production of specific motor skills, but on the dynamic interplay of person and environment.

Human motor behaviour occurs within an multidimensional space which I call *'action space'* (Figure 2).

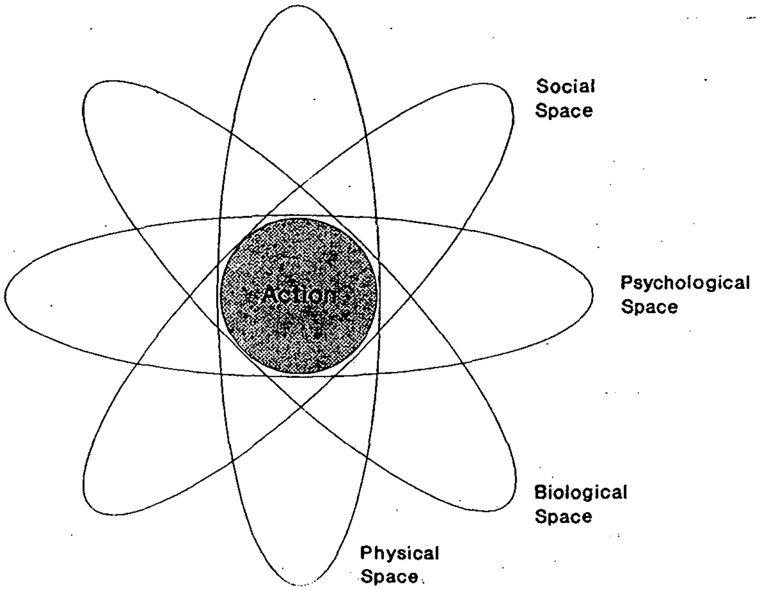

Figure 2. The action space.

The action space can be subdived into the physical, biological, psychological and social space. The central point is that our motor behaviour defines these subspaces and emerges from them at the same time.

According to this model, movements can be specifically defined and analyzed related to these four subspaces and their specific laws, as different scientific disciplines do that. However, human movement can only be completely understood and modified by taking into account the whole action space. That is, to consider human motor behaviour as behaviour of an *physical body* (kinematics and dynamics of time-space movement), an *organism* (nerves-muscles-coordination), a *personality* (purposive behaviour) and a *social beeing* (communication and interaction) at the same time (Figure 3).

With regard to Bernstein's (1967) degree of freedom problem, human behaviour must be considered to be organized under the influence of physical, biological, psychological and social constraints as well (see also Nitsch & Munzert, 1991). Physical constraints, for example, can be solid barriers or gravidity effects. Biological constraints result from our organismic constitution and functioning. Psychological constraints are consequences of the subjective definition of our situation, that is, the perceived interrelation of person, environment and task. Social constraints, finally, result from rules and norms which we are obliged to respect.

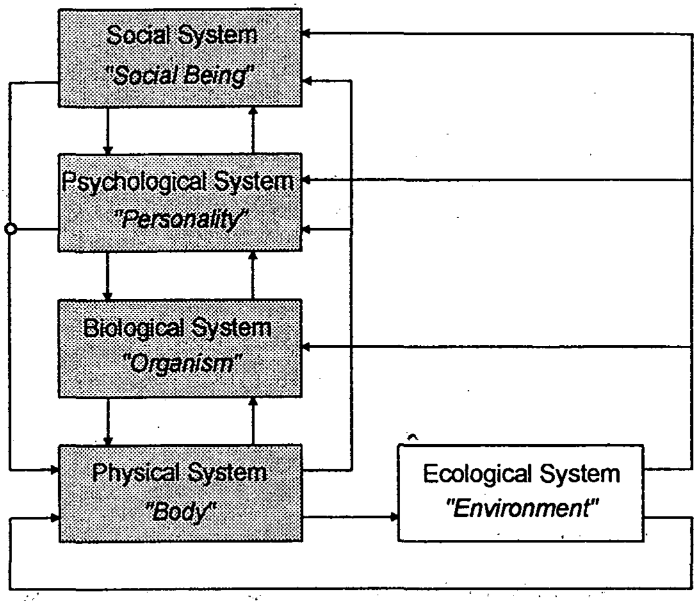

Figure 3. Organizational levels of human motor behaviour.

However, behaviour organization and motor learning are not only processes in which degrees of freedom are reduced. Particularily from a psychological point of view, they are also processes in which perceived constraints must be reduced resulting in an increase of degrees of freedom. That is, we learn to use opportunities which we assumed not to have.

Let me add an additional point derived from the behaviour-in-situation concept. Both, cognition and emotion, are not merely psychophysiological states or processes within a person as they are usually assumed to be. At least in their genesis, they are *transpersonal* relations. However, we are used to look only at one side of this relation.

An example may help to understand what is meant by this notion. The flame of a candle is not an attribute of the candle itself and cannot be explained by the components of the candle. It is an attribute of the dynamic interrelation between the wick and wax of the candle on the one hand an the oxygen in the environment on the other hand caused by a spark.

Coming back to the psychological aspect of the action space, the situation-action interrelation can be specified by the following statements:

(1) Every action is based on a subjective definition of the action situation (Figure 4). This definition refers to the constellation of person, environment and task which is appraised with respect to perceived *competence* on the one hand ("Can I cope with the situation?") and the perceived *valence* on the other hand ("Is it worthy to try this?").

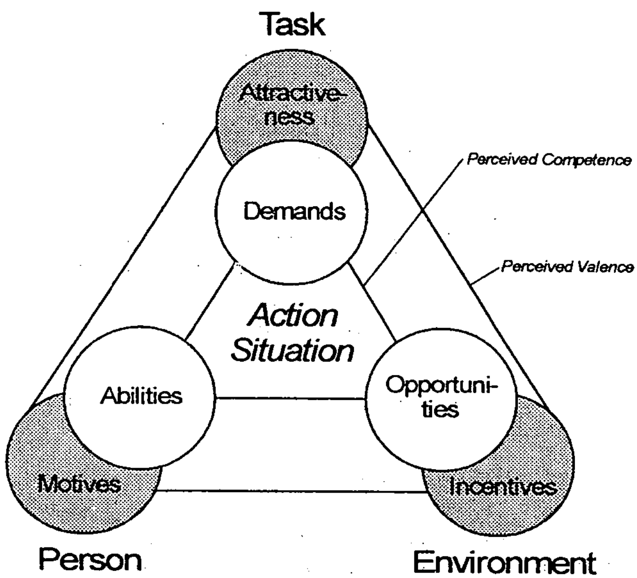

Figure 4. Components in the subjective definition of an action situation.

(2) The general intention underlying every action is to actively optimize one's situation, i.e., to maintain or regain a (relatively) favourable situation and/or to gain a higher level of adaptation. What is individually seen as 'favourable' depends on retrospection of the past and anticipation of the future (every action situation results from preceding actions and frames further actions at the same time, see Oesterreich, 1982). Furthermore, it depends on the indivudual

aspiration level (ideal situation) and on comparison with the situation of other people.

(3) By doing something in a certain manner we more or less define a situation in our own perspective and in the perspective of others as well (for example, by entering an assembly with a beer glas or a text book in one's hand). By the way, this is responsible for inforcing anxiety by anxious behaviour.

In summary, the basic purpose of an action is situation management. Consequently, motor learning can only be appropiatley understood within the frame of *action* learning.

In this sense, motor behaviour is not to be considered as production of single movements or motor skills, but as a functional organization in the process of problem solving. This idea, already formulated by Bernstein (1967), was similarily expressed by Pribram (1971) and later by Reed (1982). Pribram (1971, p. 14) points out: "Encoded in the motor cortex are the determinants of problem solution and movement, not the particular movement involved in the performance."

Human Motor Behaviour is Intentionally Organized

Motor behaviour is intentionally organized related to the subjective meaning of a given situation. According to this assumption, the accent is not laid on 'movement' per se, but on the fact that *'I move myself under certain circumstances for a certain purpose'*. However, to avoid misunderstandings, intentional organization does neither mean that movement actions are completely conscious or planned nor that the intended outcomes are subjectively considered as to be totally produced by oneself.

To give this notion an appropriate embedding, it may be useful to have a a look on what we call the *'action circle'* (Figure 5).

The outer circle in Figure 5 symbolizes that some of the situational changes occur without any intervening actions as direct effects of internal and external conditions. The middle circle indicates that motor behaviour is directly influenced by those conditions and modifies their effects. In all these cases, intentional organization of action means that these interrelations are to be taken into account in action planning.

The inner circle describes the three-phases sequence of intentional action organization (see in detail Nitsch, 1986).

In the *'anticipation phase'* the given situation is analyzed and appraised, specific intentions are generated and the course of action is planned with respect to desired outcomes. However, planning does not mean, that the total course of an action sequence must be fixed in detail before starting an action. This is only the case in 'closed' planning. Usually, we plan our actions step by step during executing an activity. This strategy of 'open' planning may be illustrated by an example. If we want to go to a certain workshop session, we firstly ask someone where it takes place. Then we go to the building picking up new information about the floor where the room is located and about how it can be reached. Arriving at the floor, we follow the arrow which points to the room location, and finally, we are looking at the numbers which indicate the rooms. That is, the action plan is specified during the action course by picking up new information (see also Seiler, 1990). Because of the fact that many aspects of the given situation and of the effects of possible alternative actions remain more or less unknown, the main problem in this phase is decision under uncertainty.

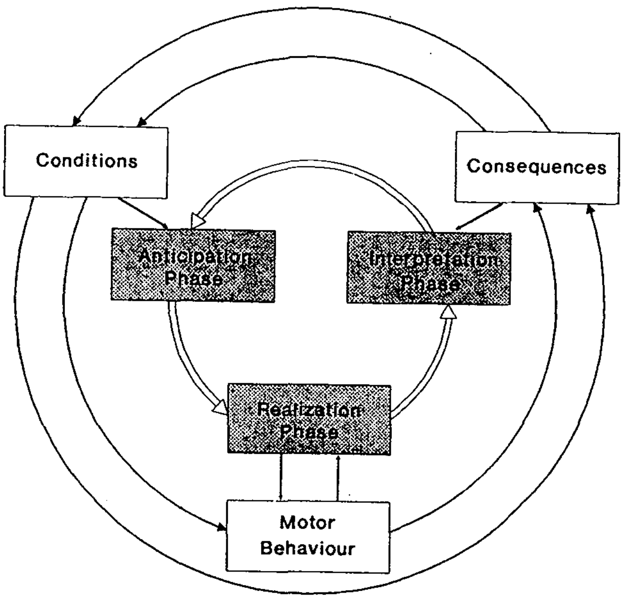

Figure 5. The action circle.

In a second step, called *'realization phase'*, we try to realize our intentions on the basis of a plan. Three problems are coming up in this phase: (a) Recognizing the situational cues for choosing the appropriate plan, (b) confrontation with reality (appropriateness of anticipation) and (c) maintaining the initial intention (protection against distracting influences).

In the final phase, the *'interpretation phase'*, the (intended and unintended) effects are analyzed, evaluated and attributed to internal and/or external causes. Problems arising in this phase are in particular related to the fact that we are often more or less unable to realistically and completely assess the results and subsequent effects of our actions by ourselves (e.g., giving an advice, or in ice dancing). Even if we could do it, we often tend to give not a realistic but a self-defending attribution.

The assumption of intentionality has some important implications.

First, intentionality necessarily implies some kind of internal representation of the person-environment interrelation. Second, the main question is not 'Why does this movement occur?', but "For what purpose is it performed?'. Therefore, movement analysis is not based on a forward strategy looking at cause-effect-sequences, but on a backward strategy which starts from the intended outcome. For example, in the first case arm-hand movement is considered as a shoulder-elbow-wrist-finger-sequence. In the second case, however, it is analyzed — and experienced — as a goal-means-sequence starting from the target to be touched (see Tholey, 1980, p. 22). Third, to realize intentions means to transform them into overt behaviour. Therefore, motor learning can be considered as learning of tranformation rules.

Finally, intentional organization is a multimodal-multilevel process. This process includes various control levels (see the final section of this paper) and specific modes of organization and regulation (Figure 6): Planning as well as guidance by ecological affordances; cybenertic control circuits as well as spontaneous self-organization, and also blocking, channeling or facilitation of our behaviour by barriers and opportunities provided by the environment or based on our specific constitution and states.

In this sense, intentions don't determine how different levels and modes are operating in detail (of course, they follow their own laws). However, intentions provide the overall functional context.

Related to these principles, motor learning includes more than acquiring motor skills, namely

- intention formation;
- defining and differentiating situational contexts;
- structuring or restructuring of plans;
- sensibilization to affordances;
- tuning the parameters of cybenertic control circuits;
- giving place to self-organizational processes;
- recognizing barriers and using the potential supports provided by the physical and the social enviroment as well.

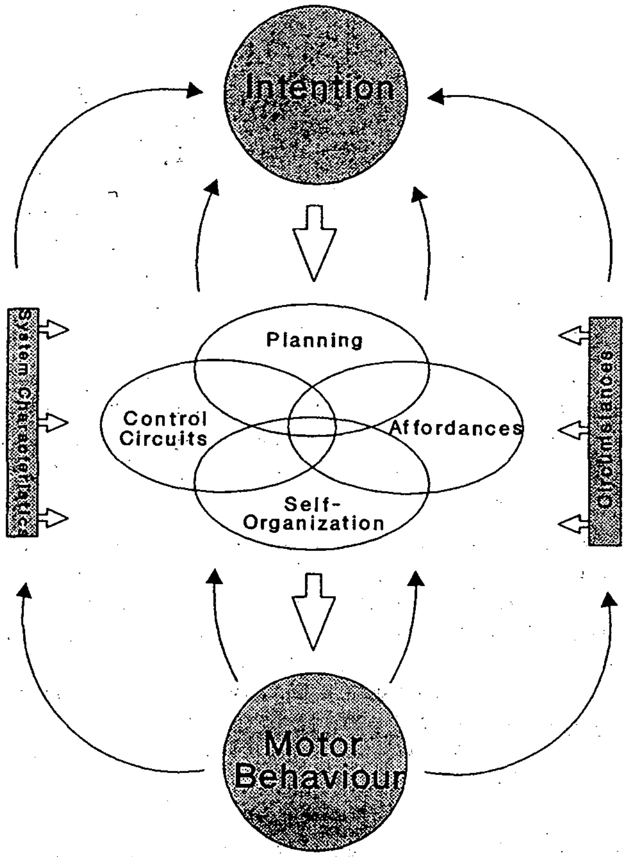

Figure 6. Factors and processes involved in the intentional organization of motor behaviour.

Motor Behaviour Plays a Constitutive Role in Information Processing

Movement is not merely a dependent variable of perception and information processing but constitutive for these processes.

This is valid for explorative behaviour and supporting movements in perception, for example turning one's head to an object. Furthermore, this applies to the definition of the quality of a perceived object by former movement experiences as well as to the internal 'matching' between perception and motor processes, as it was pointed out by Reed (1982) and Prinz (1984). That is, movement experiences and motor consequences are included in the perception of a stimulus.

In this sense, time and space perception are assumed to be dependent on action qualities, i.e., they are influenced by the relation between the potential speed of my own movement and the movement of reference objects. That is, a snail moves itself — subjectively — as fast as a mouse (except in a competitive situation). The beginner in tennis underestimates the speed of his stroke and overestimates the speed of the ball. The result is that in serving the ball the backward movement of his stroke arm is too short and the ball is thrown up not high enough. Furthermore, our time feeling is reduced, when we are unable to structure our behaviour. This is the case in boring as well as in overload situations.

Space perception depends on the subjective capability to traverse a given space. That is, time and space expand or condense depending on the action competence. Therefore, it may be that in a state of fatigue the objective speed of an executed movement has already decreased, the perceived speed, however, subjectively appears to be unchanged.

Finally, in the course of an action we attribute action-related qualities to the environmental objects we handle, for example a ball, a racket or meadows and gorges in orienteering. Based on these experiences, we do not perceive physical objects which need further interpretation. We perceive — according to a notion made by Rombach (1987, p. 350) — "frozen actions". That is, we directly perceive what we can or must do. In this case, neither planning nor decision making are explicitely involved (however, a certain intentional focus). In a certain sense, this idea may be considered as an action-theoretical expansion of Gibson's (1979) ecological approach to behaviour organization.

Psychological Processes Are Basically Related to Action Regulation

Cognitive and emotional processes, or even stress reactions have basic functions in action regulation. This includes that more or less all psychological functions are principally involved in behaviour organization. There is no action without both cognition and emotion. Extending this to a psychological perspective on control of motor behaviour three control processes (and their interrelation) are to be taken into account (Figure 7): *Cognitive control* (e.g. situation analysis, anticipation, planning), *emotional control* (e.g. emotional labeling of situations and internal tuning) and *automatic control* (e.g. automatized patterns of situation definition and responses).

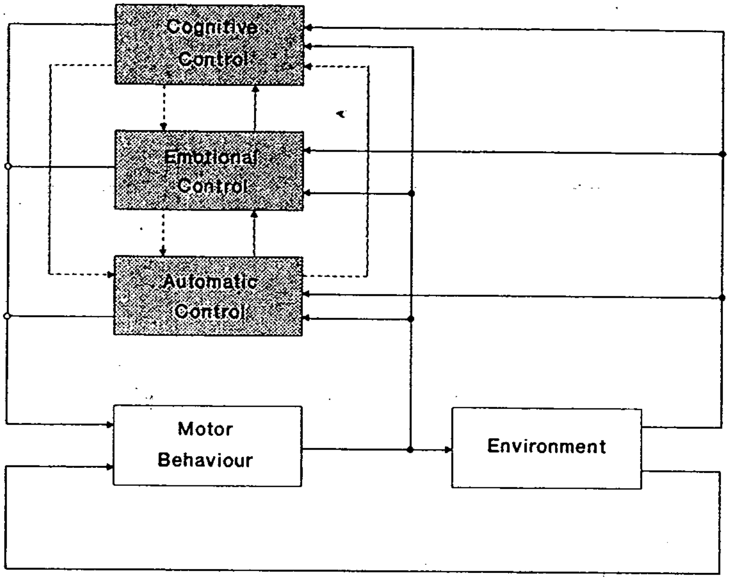

Figure 7. Psychological control systems involved in motor behaviour.

An essential implication of this conception is that psychological functions are developed and modified by the experience which results from an action. More strictly spoken, cognitive and emotional processes and their derivates (e.g. attention) are condensed internalized actions, as Galperin (1967) and van Parreren (1966) outlined.

Consequently, psychological processes must be analyzed under the question "What is both their function in action regulation and their action-related genesis?".

In this respect, emotions like anger, anxiety or happiness have an important function in the organization of motor behaviour. This function can be described as tuning both the sensori-motor system and the cognitive system. To use a chemical term, they have catalytic effects on behaviour formation. That is, emotions facilitate certain processes and modify their speed.

This seems to be in contradiction to the experience that emotions like anxiety often result in a decrease of performance. The reason for this is that an emotional preactivated behaviour pattern may be inconsistent with the pattern required in more or less artificial settings like competitive sport. Therefore, the conseqence for psychological intervention is not to eliminate emotions at all, but to establish a specific emotional state which is consistent with given demands.

To conclude, I am aware of the fact that most of the aspects and processes mentioned above are not sufficiently elaborated until now. What we need is not only a subtle understanding of these processes themselves. Far beyond this, we are still missing a conception of their dynamic interplay within human behaviour organization. Therefore, what we urgently need is research on the background of an integrative theoretical frame of reference. Thus, developing a comprehensive theoretical conception of motor behaviour in the sense of intentional organized behaviour-in-situation is the task which we primarily have to deal with in the future.

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GESTALTGESETZE UND BEWEGUNGSSTRUKTUR - ZUR ANALOGIE IMPLIZITER ORDNUNG

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Einleitung

Die Wirkung des Sportpsychologen transformiert sich vielfach gebrochen in sportliche Leistung. Das vermittelnde Glied ist die Bewegung als Schnittstelle zwischen dem Subjekt Sportler und dem Objekt Aufgabe. Bewegungen sind, soweit man den Stand der Erkenntnisse reflektiert, jedoch keinesfalls eine Kopie oder lineare Reproduktion des Wollens und Könnens eines Sportlers, sondern offenbaren bei näherer Betrachtung eine beachtliche Eigendynamik. Es finden komplexe Ordnungsbildungen räumlicher und zeitlicher Art in den kinematischen Endgliedern statt, die oft nur zum Teil bewußtseinsfähig oder bewußtseinpflichtig sind, ungeachtet dieses Faktes aber der Zielerreichung der Gesamtbewegung dienen. Begriffe wie Ganzheit, Struktur oder auch Gestalt werden geprägt, um die Phänomenologie, Kausalität und Genese der Motorik jenseits einer diffusen und undifferenzierten Holistik faßbar zu machen.

In einem von Max Wertheimer, Mitbegründer der klassischen Gestalttheorie, 1924 gehaltenem Vortrag wird bereits ausdrücklich vermerkt, daß Gestalttheorie nicht nur aus den Problemen der Arbeit erwachsen ist, sondern für die Arbeit da sei. In analoger Weise ist ein Bezug von Gestalttheorie und Bewegungsregulation etwas aus der unmittelbaren Beschäftigung mit dem Phänomen Bewegung Hervorgegangenes. Folgerichtig hat die moderne Psychologie die Motorik mit ihren komplizierten Strukturen als bedeutendes gestaltpsychologisches Experimentier-, Erkenntnis- und Validierungsfeld wiederentdeckt. Beleg dafür sind die Arbeiten von Stadler und Kruse (1986), Tholey (1980, 1987), Wehner und Mehl (1986), Volpert (1986) und Vogt (1988). Weit weniger Aufmerksamkeit, dennoch exponiert durch Kurt Kohl vertreten (1956, 1988), sind die Denkansätze, die aus dem Gegenstandsbereich der Sportwissenschaft heraus gestaltpsychologisches Gedankengut rezipieren und nutzbar machen. Unter mehr philosophischen Aspekt einer Teil-Ganzes-Dialektik gibt es in jüngster Zeit solche Versuche von Prohl und Scheid (1990).

Der Begriff Gestalt ist in diesem Kontext von zentraler Bedeutung und wird durch Wehner und Mehl (1986) in der Art formuliert, daß gegebene Handlungsteile nicht additiv verknüpft werden, sondern in einer dynamischen übersummativen Abhängigkeit stehen. Sie führen weiter aus: "Gestalten weisen Prägnanztendenzen auf, d.h., daß sich die Handlungsteile während der Interaktion durch Zentrierungs- und

Umstrukturierungsprozesse den Prägnanzprinzipien (Gesetz der Nähe, der Gleichartigkeit, usw.) folgend verändern" (S. 233).

Volpert (1986, S. 43) verwendet gleichfalls den Begriff der Gestaltbildung im Handeln und Kohl (1988, S. 47) versinnbildlicht damit den Fakt komplexer Strukturbildung in der Einheit von Empfindung und Bewegung. Folgt man dem Grundgedanken dieses Konzepts, so unterliegen implizite Ordnungs- oder Gestaltbildungen in der Bewegung, in der Wahrnehmung, im Denken und Fühlen übergreifenden Regeln. Der Form nach realisieren sich diese Regeln in den sogenannten Gestaltgesetzen, welche in ihrem Kern nichts anderes als systemimmanente Strukturierungsprinzipien darstellen und derzeit in den modernen Selbstorganisationstheorien unter z.T. anderen Namen eine gewichtige Rolle spielen (vgl. Stadler & Kruse, 1986). Insofern liegt eine Übertragung auf die Motorik nahe.

Die 114 formulierten klassischen Gestaltgesetze (vgl. Dorsch, 1970) und 744 Nichtsummativitätsbegriffe (vgl. Rausch, 1966, S. 886) verdeutlichen aber auch die Problematik einer konstruktiven Analogiebetrachtung in Bezug zur Motorik.

Ohne Anspruch auf Vollständigkeit und im Bewußtsein, diesen sehr komplexen Gegenstand nur ausschnittsweise behandeln zu können, seien einige wenige Aspekte impliziter Ordnungsbildung in der Bewegung gestalttheoretisch betrachtet.

Bewegungsstrukturen und Gestaltgesetze

Strategienbildung und Gesetz der guten Gestalt

Bewegungen werden bei gleichem Resultat oft sehr unterschiedlich durchgeführt. Ein und dieselbe Leistung kann über unterschiedliche Strukturen realisiert werden. Was den Begriff der Strategie hierbei ausmacht ist der Fakt, daß nicht jede mögliche Struktur realisierbar ist, sondern nur bestimmte ausschnittsweise Bereiche genutzt werden (vgl. Bernstein, 1988; Nasher & McCollum; 1985, Loosch, 1990). Eine Analogie dieses Phänomenes ergibt sich zum Gesetz der guten Gestalt oder dem Prägnanzprinzip, dem wohl universellsten Axiom und einem Schlüsselkonzept der Gestalttheorie (vgl. Rausch, 1966, S. 905; Kanizsa & Luccio, 1986). Ohne auf die z.T. sehr diffizilen und definitorisch nicht immer klaren terminologischen Abstufungen einzugehen, kann Prägnanz hierbei für Gliederung, Bezugssystem, Zentrierung und Ordnung angenommen werden. Die postulierten Prägnanzstufen eines Ganzen (vgl. Rausch, 1966, S. 904ff.) entsprechen der Herausbildung verschiedener Strategien der Bewegungsregulation. Der Begriff der guten Gestalt ist in seiner fast unwissenschaftlich scheinenden Antiquiertheit dann zutreffend, wenn man die energetischen und emotionalen Komponenten einer fließenden und gekonnt ausgeführten Bewegung ins Kalkül zieht. Ausführlicher hat sich Vogt

(1988, S. 37) in Bezug auf die Ausführungen Metzgers (1982) mit letzterer Problematik beschäftigt.

Die Möglichkeit der Verallgemeinerung des Prägnanzprinzips auch auf Fragen der Motorik hat bereits Metzger (1982), einer der bedeutendsten Vertreter der modernen Gestalttheorie, hervorgehoben.

Individuelle Invarianz und Identitätserhaltung

Individuelle Bewegungsstrukturen weisen außer ihrer Einordnung in bestimmte Strategien eine weitere Eigenschaft auf. Durch Verlangsamung oder Beschleunigung einer Bewegung, durch räumliche oder kräftemäßige Variation werden diese innerhalb bestimmter Grenzen als ganzheitliche Strukturen, d.h. in Relation ihrer Teilzeiten, Teilkräfte, Teilparameter und Abfolgen (relatives Timing, relativer Krafteinsatz, Sequencing) nicht verändert (Schmidt, 1984; Roth, 1989). Die "Gestalt" bzw. die Identität der Struktur bleibt erhalten (vgl. Rausch, 1966, S. 884). Diese Eigenschaft ist insbesondere aus dem Wahrnehmungsbereich als Transponierbarkeit bekannt. Das klassische und bis heute zitierte Beispiel stammt von v. Ehrenfels (1890): Melodien können zeitliche Variationen oder Tonhöhenänderungen als Ganzes erfahren, ohne daß ihre spezifische "Gestaltqualität" verloren geht.

Variabilität von Teil und Ganzem und Nichtsummativität

Untersucht man zielgerichtete Bewegungen bezüglich unterschiedlichster Parameter, so wird deutlich, daß der Variabilitätskoeffizient der Zielgröße keineswegs die Summe der Variabilitäten der Teile repräsentiert, sondern deutlich geringer ist als diese, oft auch geringer als deren Mittelwert und im Extremfall geringer ist als die kleinste Teilvariabilität (vgl. Drill, 1933; Lee, 1980; Loosch, 1990). Gegenüber der weitaus größeren Schwankungen der Teile ist das Ganze stabil.

Zugleich wird das Ganze wesentlich empfindlicher gegenüber dem Einfluß der Teile. Werden von einzelnen Teilbewegungen bestimmte Variabilitätsgrenzen nur geringfügig überschritten, so kommt es zu einem Zusammenbruch der Gesamtbewegung. In beiden Mechanismen manifestiert sich das Phänomen der Nichtsummativität. Wesentliche Postulate der Gestalttheorie spiegeln sich in diesen Fakten wider.

Wechselwirkung zwischen Teil und Ganzem und Korrelativität

Untersucht man die Wechselwirkungen von Teilbewegungen im Lernprozeß, so werden zwei Tendenzen sichtbar. Erstens verstärken und differenzieren sich die statistischen Korrelationen im Verlaufe des Lernprozesses zwischen den Teilen eines Bewegungsvollzuges. Zweitens sinkt die Korrelation zwischen Teil und Ganzem als Ausdruck zunehmender Unabhängigkeit des Ganzen von den Teilen (vgl. Loosch, 1990, S. 100ff.).

Dem entspricht das Axiom der Korrelativität, wie es Rausch (1966, S. 892) benennt und welches Prinzipien der Wechselwirkung in Gestalten formalisiert.

Schlußbemerkungen

1. Der oft gegangene Weg sportpsychologischer und sportmotorischer Diagnostik liegt im Zergliedern von ganzheitlichen Strukturen. Dieses Vorgehen impliziert zugleich die Gefahr, wesentliche Teile autonomer Ordnungsbildungen dieses Ganzen zu vernachlässigen. Praktische Bedeutung erlangt diese Gefahr dort, wo aus der Summe diagnostizierter Teilleistungen auf sportartspezifische Gesamtleistung geschlußfolgert wird. Es geht hierbei keineswegs um globalisierende Kritik an diesem Vorgehen, zu dem es keine Alternative gibt, sondern es geht um das Problembewußtsein, welches solcherart erhobenen Daten entgegengebracht wird. In diesem Sinne sind Analogiebetrachtungen über implizite Ordnungen in sehr unterschiedlichen Anwendungsfeldern mehr als nur ein Theoriekonzept, denn als Ausgangspunkt eröffnen sie die Möglichkeit, die inneren Gesetzmäßigkeiten des Gegenstandes besser zu verstehen und effizienter in Diagnose- und Interventionskonzepte einzuordenen.

2. Die Psychologie hat die Bewegung gezielt zu einem Prüffeld ihrer Theorien zur Gestaltbildung erhoben. Die Aufarbeitung der Gestalttheorie seitens der Motorik findet demgegenüber deutlich weniger Beachtung. Wo dies jedoch geschieht, werden in der Motorik Zusammenhänge zwischen Phänomenen der Bewegungsregulation und Gestaltgesetzen weitgehend unter dem Aspekt einer Analogiebetrachtung vorgenommen. Es gibt kaum Ansätze, in denen die für die Wahrnehmung sehr detailliert beschriebenen Strukturprinzipien als Hypothesen für die Bewegungsanalyse dienen, obgleich ein solcher Zugang durchaus Erkenntnisfortschritte für die Motorik beinhalten könnte.

3. Im allgemeinen Kontext einer wachsenden Wissens- und Wissenschaftsintegration auch sehr heterogener Disziplinen liegen wesentliche Impulse für die Sportpsychologie. Die sechs Prinzipien eines Lehrens und Lernens sportlicher Handlungen aus gestaltpsychologischer Sicht, wie sie von Tholey (1987) aufgestellt wurden, verdeutlichen die bis in übungsmethodische Ableitungen hinein reichenden Schnittstellen zwischen Motorik und Gestalttheorie.

Die große Autonomie der Bewegungsregulation, wie sie die Gestalttheorie und die Selbstorganisationskonzepte postulieren (z.B. bezüglich Stabilität und Variabilität) stellt aber auch die Frage nach dem Eingriffsspielraum in motorische Leistungen, den Psychologen haben.

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Zur Kontrolle von Freiheitsgraden beim motorischen Lernen

oder: Wie stark muss dieser Prozess kognitiv penetriert werden?

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Das Problem der Freiheitsgrade - ein Scheinproblem?

Versteht man unter motorischem Lernen den Erwerb und die Optimierung von Bewegungen, so stellt sich die zentrale Frage, welches psychologische Modell diesen Prozeß am effizientesten erklärt. Natürlich lassen sich direkt eine Reihe von mehr oder weniger stark auf die Motorik orientierten Lernmodellen auflisten, wie z.B.

- behavioristische Ansätze
- Regelungstheorien
- Schematheorien, usw.

Die verschiedenen Vor- und Nachteile dieser Ansätze sind in der Literatur ausführlich diskutiert worden, beispielsweise bei Zimmer und Körndle (1989) und Zimmer (1990). Hier möchte ich einen etwas anderen Weg gehen, um das Phänomen "Motorisches Lernen" zu behandeln:

Resultat eines Lernprozesses ist eine koordinierte Bewegung, d.h., bei ihrer Ausführung werden eine Vielzahl von Muskeln zunehmend so gesteuert, daß daraus die gewünschte Bewegung resultiert. Eine Kenngröße für den dabei zu leistenden Steuerungsaufwand ist die Anzahl der sog. Freiheitsgrade der Bewegung.

Die Anzahl dieser Freiheitsgrade bestimmt sich als Summe der orthogonalen Raumkoordinaten, in die sich die an der Bewegung beteiligten Gelenke bewegen können. So hat z.B. ein Zylindergelenk nur 1 Freiheitsgrad, ein Kugelgelenk dagegen 3 Freiheitsgrade. Insgesamt ergeben sich bei dieser Aufsummierung 127 bis 792 Freiheitsgrade für den menschlichen Körper (Bernstein zählt unter Berücksichtigung verschiedener mechanischer bzw. biomechanischer Constraints 127 Freiheitsgrade). Bei der Ausführung einer Bewegung müssen diese Freiheitsgrade so gesteuert und kontrolliert werden, daß eine koordinierte Bewegung entsteht. Wie kommt diese Steuerungsleistung zustande?

Klassisch überwiegen bei der Klärung dieser Frage die sog. Repräsentationstheorien. Sie gehen davon aus, daß Bewegungen als Gedächtnisinhalte gespeichert sind, die durch Lernen verändert werden können. Wichtige Gedächtnisinhalte sind z.B. auch allgemeine Kenntnisse über wahrnehmbare Eigenschaften der Umwelt und des eigenen Körpers. Aufgrund dieser Gedächtnisinhalte sind die Akteure in der Lage, zielgerichtetes Handeln und Bewegen in der Umwelt zu planen.

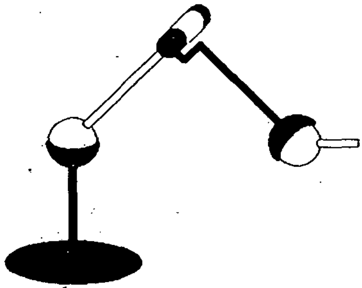

Abbildung 1. Ein Modellarm, bestehend aus 2 Kugelgelenken und 1 Zylindergelenk. Dieses Modell hat 7 Freiheitsgrade (aus Hollerbach, 1990).

Für die Kontrolle der vielen Freiheitsgrade liefern die Repräsentationsansätze keine Lösung, da die Freiheitsgrade auf eine mentale Ebene ohne weitere Reduktion abgebildet werden. Außerdem droht die Gefahr einer Homunculus-Theorie: Ein (virtueller) Akteur im Kopf des sich Bewegenden muß dessen (virtuelles) Verhalten wahrnehmen, um es schließlich gezielt nach einer Rücktransformation real ausführen zu können.

Neben wissenschaftstheoretischen Überlegungen sprechen auch experimentelle Daten gegen Repräsentationsansätze: Bei hochgeübten Tätigkeiten sollte die interne Repräsentation den Akteuren eine präzise wiederholbare Bewegungsausführung unter denselben Situationsbedingungen erlauben. Daten von Spitzensportlern zeigen aber hohe Variabilität. Sie muß im Sinn von Stelmach und Diggles als motorische Variabilität verstanden werden, d.h. Bewegungen werden nicht nur auf der Basis einer mentalen Repräsentation erzeugt.

Der Lösungsvorschlag des ökologischen Realismus: Affordances und Effectivities

Eine radikal andere Lösung des Freiheitsgrad-Problems liefert der ökologische Realismus: Danach ist die Annahme einer internen Repräsentation unsinnig, da dabei der Organismus und die Umwelt, in der er agiert, getrennt gesehen werden.

In Wirklichkeit würden Bewegungen i.S. Gibsons durch das gesetzmäßige Ineinandergreifen von affordances (nämlich Handlungsmöglichkeiten in der Umwelt, die der Organismus direkt wahrnehmen kann) und effectivities (Bewegungsmöglichkeiten des Organismus in seiner Umwelt) erzeugt: Die Freiheitsgrade würden also durch die Organismus-Umwelt-Interaktion so "gesteuert", daß eine koordinierte Bewegung resultiert, dabei ist die Annahme einer Instanz zur Steuerung von Freiheitsgraden in diesem Ansatz nicht notwendig.

Speziell die Gruppe um M. Turvey versucht seit langem, diesen Ansatz des ökologischen Realismus experimentell zu operationalisieren. Das von ihr untersuchte Bewegungsrepertoire umfaßt vor allem Alltagsbewegungen. Periodische Bewegungen, wie z.B. das Gehen und Laufen resultieren in diesem Ansatz aus der Interaktion mit der Umwelt, wobei aus dieser Interaktion Oszillationen entstehen. Für das Beispiel "Gehen" bildet dabei das Bein den mechanischen Oszillator, die Annahme eines mentalen Oszillators oder einer mentalen Repräsentation ist in diesem Beispiel überflüssig. Die empirische Tragfähigkeit dieses Ansatzes findet man u.a. auch an Holzspielzeugtieren bestätigt, deren vier Beine Lokomotionsbewegungen zeigen, wenn dieses Spielzeug z.B. über eine Tischplatte gezogen wird.

Zweifelsohne läßt sich mit der Annahme solcher Mechanismen das Freiheitsgrad-Problem auf den ersten Blick massiv reduzieren. Periodische Bewegungen entstehen ausschließlich durch die Verkopplung von affordances und effectivities ohne eine Repräsentationsannahme z.B. in Form eines Bewegungsplans.

Ein Experiment, das nicht-reproduzierbare Daten liefert

Turvey, Rosenblum, Schmidt & Kugler (1986) haben die Idee, Gehen als Interaktion von Bein und Umwelt zu modellieren, in einem Experiment überprüft. Die Experimentalanordnung besteht darin, daß Probanden zwei Holzstöcke in den Händen halten und möglichst bequem pendeln lassen sollen. Turvey et al. gehen davon aus, daß damit typische Lokomotionsbewegungen von Säugetieren untersucht werden können. Das ist der Grundgedanke dieses Experiments.

Die zentrale Aussage ihrer theoretischen und experimentellen Untersuchungen ist, daß unterschiedlich lange Pendel (mit unterschiedlichen Eigenfrequenzen) bei dieser Experimentalanordnung nicht mit ihren Eigenfrequenzen bewegt würden, sondern daß die Probanden die beiden unterschiedlichen Pendel auf eine gemeinsame Frequenz synchronisieren würden. Sicher ist das eine wichtige Eigenschaft, wenn man mit solchen gekoppelten Pendeln Lokomotionsbewegungen simulieren und modellieren will: Beispielsweise erlaubt dieses Kooperationsprinzip eine synchrone Bewegungsausführung auch für unterschiedliche oder sich ändernde Einzelpendel bzw. Beine, wie es beim Gehen und Laufen über unebenem oder steilem Terrain der Fall ist.

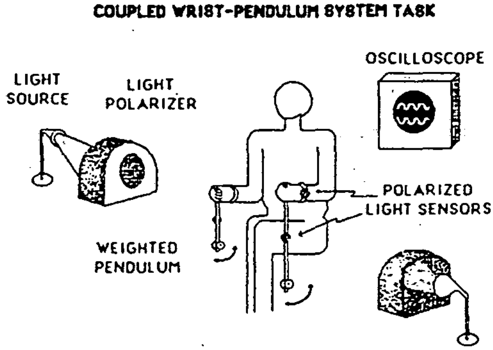

Abbildung 2. Die Experimentalanordnung von Turvey et al. (1986) zur Untersuchung von Pendelbewegungen.

Allerdings hat die ganze Angelegenheit einen Haken: Die experimentellen Daten konnten wir nicht reproduzieren. Bei Wiederholung des Experiments findet sich keine gemeinsame Mittenfrequenz der beiden unterschiedlichen Pendel. Ein möglicher Grund liegt in der Verletzung verschiedener Begriffe: Turvey benutzt bei seinen theoretischen Ableitungen die Schwingungsgleichung für ein physikalisches Pendel. Sie beinhaltet, daß ein Pendel eine bestimmte Eigenfrequenz besitzt, die von der Pendellänge abhängt. Eigenfrequenz bedeutet aber, daß das Pendel unabhängig von der Erregungsfrequenz immer mit dieser Eigenfrequenz schwingt.

Aus dieser Begriffsverletzung resultieren zwei mögliche Konsequenzen:

(a) Man überprüft mit einer neuen Experimentalanordnung unter Verwendung von physikalischen Pendeln (Eigenfrequenz!) Turvey's theoretische Annahmen bezüglich der direkten Kopplung,

oder

(b) Man akzeptiert Turvey's Experimentalanordnung als Prototyp für direkte Kopplung.

Alternative (b) hat die Eigenart, daß ihre korrekte physikalische Beschreibung außerordentlich kompliziert wird (force driven oscillators) und so keine Freiheitsgrade reduziert: Damit ist Turveys Experimentalanordnung also für die Untersuchung der intendierten Fragestellung ungeeignet.

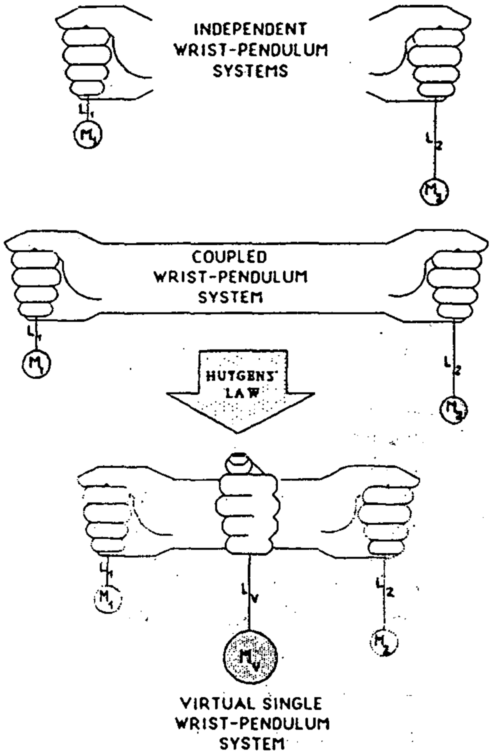

Abbildung 3. Die Prognose von Turvey et al. (1986) über die von den Probanden zu erwartende Pendelbewegung. Der Originaltext lautet: Applying the "compound-pendulum" to "simple-pendulum" transformation (Huygens' law) to a coupled pair of wrist-pendulum systems. (In the resultant virtual single wrist-pendulum system it is as if all the mass Mv is concentrated at a single point at distance Lv from a virtual point of rotation).

Pendel mit Eigenfrequenz

$$T = 2\pi\sqrt{\frac{l}{g}}$$

(l = Länge des Pendels,
g = Erdbeschleunigung)

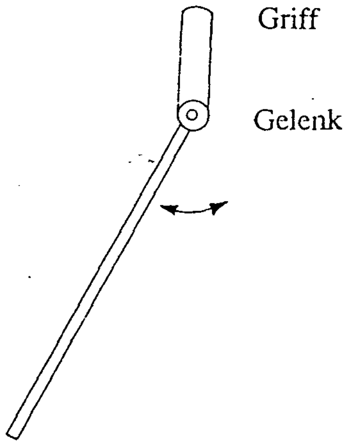

Abbildung 4. Schwingungsgleichung und mögliche Realisierung eines physikalischen Pendels.

Eine alternative Versuchsanordnung

Aufgrund obiger Überlegungen verfolgten wir Alternative (a). Ein Experiment mit physikalischen Pendeln liefert im wesentlichen folgendes Ergebnis:

1) Zu Beginn des Experiments erregen die Probanden beide unterschiedlichen Pendel links und rechts mit gemeinsamen Frequenzen, während

2) mit zunehmender Experimentaldauer die Pendel immer stärker mit ihrer Eigenfrequenz bewegt werden.

Inhaltlich bedeutet das, daß die Probanden lernen, jede Hand mit einer bestimmten Frequenz zu bewegen. Daraus ist der Schluß zu ziehen, daß Oszillatoren nicht unbedingt in Form von pendelnden Extremitäten realisiert, sondern anderer, z.B. neuronaler Natur sein können. Solche Taktgeber müssen die Eigenschaft haben, daß sie in ihrer Taktfrequenz modulierbar sind.

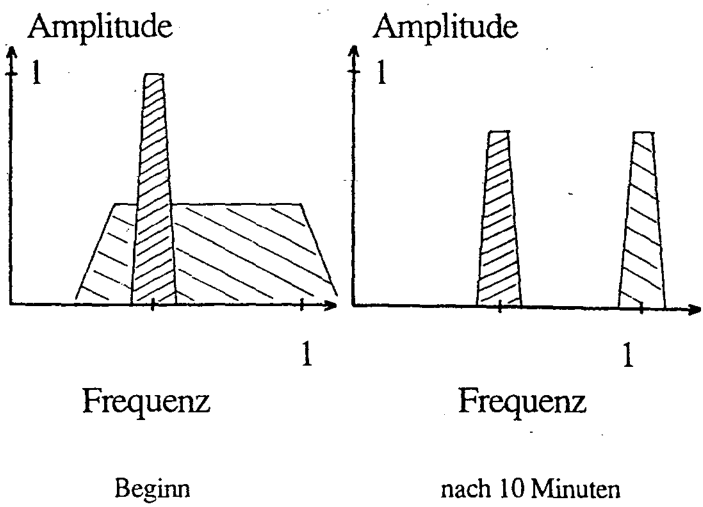

Abbildung 5. Ergebnis des Experiments mit physikalischen Pendeln in Form von Frequenz-Amplituden-Darstellungen. Links: Frequenzspektrum der beiden Pendel zu Beginn des Experiments. Rechts: nach 10 Minuten Dauer des Experiments.

Fazit: Ökologischer Realismus — experimentell ernst genommen

Bezieht man die Position, daß Turvey's Experimentalanordnung nicht geeignet ist, die Entstehung von Bewegungen direkt aus der Organismus-Umwelt-Interaktion zu erklären, so ist man deswegen nicht gezwungen, die Ideen des ökologischen Realismus aufzugeben. Allerdings muß man dann andere Experimentalanordnungen zu seiner Operationalisierung vorschlagen.

Einen Lösungsweg bieten m.E. Synergetik-Modelle (Haken, 1983), da sie wenige allgemeine Annahmen bezüglich des Interaktionsgeschehens machen und auf explizite Mechanismen, die Ordnung erzeugen (wie z.B. Oszillatoren), verzichten: Oszillationen entstehen durch Interaktionen in nicht weiter spezifizierbaren Vielteilchensystemen. Diese Vielteilchensysteme werden unter makroskopischem Aspekt betrachtet. Diese Systeme sind offen und fernab eines (thermodynamischen) Gleichgewichts.

Organismus und Umwelt sind z.B. als Vielteilchensysteme zu verstehen, wobei die Teile beliebig miteinander interagieren können. Ein wesentliches Resultat dieser Interaktionen ist eine Musterbildung, wobei die Art der Muster nur von einem oder einigen wenigen Control-Parametern abhängt. Solche Systeme zeigen u.a. auch Multistabilität, d.h., in Abhängigkeit von der Größe des Control-Parameters zeigt das System verschiedene stabile Muster (z.B. Gehen - Laufen). Der Übergang zwischen den Mustern ist mit Hysterese behaftet.

Fest steht, daß nahezu alle Leistungen, die ein synergetisches System zeigt, nicht durch eine ordnende Instanz repräsentiert sein müssen. Für die Control-Parameter z.B. wird man jedoch eine Repräsentation fordern. Insofern sind die eingangs konträr formulierten Ansätze eher als komplementär zu verstehen: Fragen des motorischen Lernens wird man also weder ausschließlich mit einem Repräsentationsansatz noch aussschließlich mit einem Interaktionsansatz beantworten wollen.

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From Walking to Running: Study of Energy Correlates

Marc Durand, Christine Goudal, Jacques Mercier, Daniel Le Gallais, and Jean Paul Micallef, France

Introduction

The existence of an optimal walking speed is a well-known fact (Ralston, 1958; Zarrugh, Todd & Ralston, 1974), i.e. at a certain speed, energy expenditure is at its minimum. Moreover, an optimal stride amplitude/frequency ratio has been defined for all walking speeds (Cavagna & Franzetti, 1982; Cavagna & Kaneko, 1977; Ralston, 1958; Zarrugh, Todd, & Ralston, 1974) and running speeds (Cavanagh & Williams, 1982; Hogberg, 1952; Kaneko, Ito, Fuchimoto, Shishikura, & Toyoka, 1987; Knuttgen, 1961). Finally, subjects are not only capable of walking at the optimal speed (task permitting) (Hogberg, 1952), but when their displacement speed is imposed, they are also capable of establishing the optimal amplitude/frequency ratio in both walking (Inman, Ralston, & Todd, 1981; Zarrugh, Todd, & Ralston, 1974) and running (Cavanagh & Williams, 1982; Kaneko et al., 1987; Lin, 1980).

However, this ability to minimize energy expenditure has only been found when the level of constraint chosen or imposed by the task corresponds to what Warren (1984) calls the "optimal point" or "optimal zone". The question that remains is whether the optimization process still occurs when the task demands fall within a "critical zone". Warren (1984) used these terms to refer to situations in which the task requires the subject to change motor programmes or adopt a different type of programme (for a review, see Durand, in press).

The above question can also be raised in the study of motor tasks and sports activities. Indeed, it appears possible (Famose, Bertsch, Champion & Durand, 1983) to define the tasks performed by sports participants in terms of a set of ordinal descriptors for rating the subject's behavior (Durand, 1991). These descriptors correspond to characteristics which the teacher or trainer can modify in order to promote learning or trigger the desired adaptation by the sports student.

Few studies have analyzed the nature of the processes at play when quantitative modifications in the task (increases or decreases in task demands) cause quantitative modifications in behavior (changes in motor pattern). The present experiment was thus designed to study this issue using the walking-running transition zone as an experimental paradigm. When individuals are confronted with a task requiring displacement at a faster and faster speed, they first adapt by modifying their walking speed, and then by running at an increasingly fast rate (Thorstensen & Roberthson, 1987). There is indeed a critical point which defines the moment at which the change in motor pattern takes place. From the standpoint of energy expenditure, this transition is interesting because it corresponds to an inversion: below a certain speed it is "more economical" to walk than to run, while above that speed, it is "more economical" to run than to walk (Astrand & Rodahl, 1980).

Is the choice of a locomotor mode an optimization process? Does the change in motor program occur at the speed at which the "energy inversion" takes place?

Method

Subjects

The nine subjects were male students at the University of Montpellier, France. All participated regularly in some sports or other physical activity. Their anthropometric and physiological characteristics are presented in table 1.

	AGE years	WEIGHT kg	HEIGHT m	LENGTH legs	VO_2max ml/kg*min
Subject 1	25	80	1.78	0.92	60.93
Subject 2	25	70	1.74	0.93	60.34
Subject 3	23	64	1.80	1.07	62.01
Subject 4	25	78	1.76	1.03	51.60
Subject 5	23	81	1.88	0.98	61.88
Subject 6	25	69	1.74	0.95	54.45
Subject 7	20	69	1.70	0.85	41.68
Subject 8	24	78	1.78	0.90	56.62
Subject 9	24	85	1.85	0.94	61.85
Mean	23.78	74.89	1.78	0.95	56.82
S.D.	1.64	7.04	0.06	0.06	6.79

Table 1. Anthropometric and physiological characteristics of the subjects.

Procedure

Each subject was tested once a week for four weeks in four phases: familiarization and measurement of maximum oxygen uptake (phase 1), self-paced test (phase 2), walking speed test (phase 3), and running speed test (phase 4).

Phase 1. After a period of familiarization with the treadmill (Gymroll), VO_2max was measured using a conventional technique. The treadmill speed was increased every 4 minute by 0.5 km/hr, and the subjects' breathing patterns were measured by the open circuits method.

Phase 2. The subjects were told they would be performing an increasingly demanding treadmill exercise. They were to begin by walking, and then at some point, would have to run. They were instructed to move in a comfortable manner. The test began with a treadmill speed of 5 km/hr. Its speed was incremented by 0.5 km/hr every 4 minutes. Once the subject started running, the pace was increased exactly two more times.

Throughout the test, oxygen uptake (VO_2) and heart rate (HR) were measured with the devices used in phase 1. At the same time, the subjects were filmed on videotape (sampling frequency: 50 Hz).

Phase 3. During the third phase, the same measures were taken as in phase 2, but the subjects were required to walk for the entire range of speeds, i.e., 3 increments below the transition speed and 3 increments above.

Phase 4. This phase was analogous to phase 3 in all respects, except that the subjects ran instead of walking.

Results

The results indicated that subjects chose to begin running at various speeds ranging from 7.5 to 9.5 km/hr (mean: 8.05 km/hr). Using each subject's transition speed as a comparison point, we can see that the transition occurred precisely when walking and running involved comparable oxygen uptakes (Figure 1) and heart rates (Figure 2).

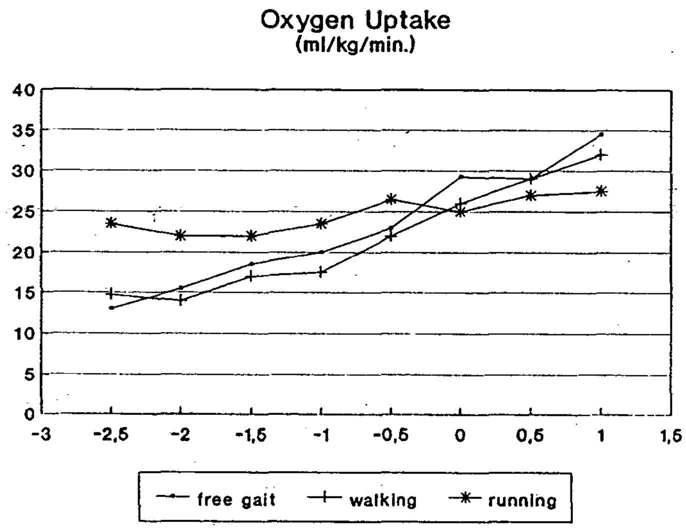

Figure 1. Mean oxygen uptake during walking, running, and self-paced displacement. (The asterisk indicates the speed at which each subject began running.)

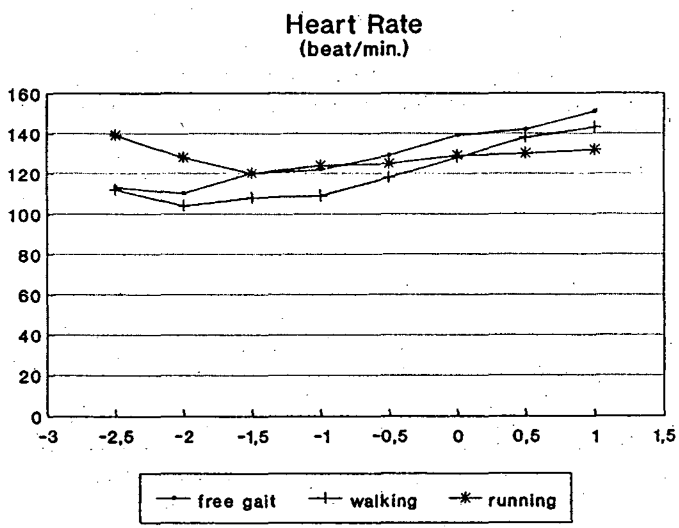

Figure 2. Mean heart rate during walking, running, and self-paced displacement. (The asterisk indicates the speed at which each subject began running.)

Discussion

The main finding of this experiment is that the transition from walking to running is in fact the result of an optimization process: the change in motor program corresponds to the minimization of energy expenditure, as measured by oxygen uptake and heart rate.

Substantial interinvidivual differences were observed, but excluding one quite unique subject, the mean transition speed was 7.88 km/hr. This corresponds to the figure quoted in the literature.

The question which remains concerns the nature of the control processes underlying the transition. Schematically, two opposing explanations can be given.

The first ascribes a major role to cognitive processes. Under this hypothesis, subjects perceive the amount of effort exerted and the cost of that effort, compare that information with some presumably pre-stored knowledge about the amount of energy required to run, and then decide whether or not to change programs in order to minimize expenditure. This is a very general decision-making model wherein energy expenditure provides useful data for determining behavior.

The second explanation assumes that the implementation of these adaptation processes is not the result of a calculation. Under this hypothesis, the dynamic and kinematic characteristics of the movements involved are not anticipated and represented cognitively, but depend instead on the biomechanical features of the motor system. The change in motor programme is assumed to occur in a virtually automatic fashion, and the minimization of energy expenditure to be a consequence of a general principle of economy.

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DIE EEG-GRUNDAKTIVITÄT BEI PSYCHOMOTORISCHEN ANFORDERUNGEN

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Anliegen

Neurophysiologische Grundlagenforschung analysiert u.a. für die Handlungsregulation bedeutsame zentralnervale Prozesse. Eine Möglichkeit ihrer Erfassung ist die Ableitung der EEG (Elektroenzephalogramm)-Grundaktivität (im Text kurz EEG).

Mit spektralen und Zeitreihenparametern des EEGs kann das Aktivitätsniveau des ZNS charakterisiert werden, wobei Aktivierung und Wachheit mit Desynchronisation, und Entspannung bzw. Ruhe mit synchronisierter Aktivität von Neuronen einhergehen. Nach Creutzfeld (1983) ist "der Synchronisierungsgrad der Hirnaktivität von einer Vielzahl von Variablen abhängig, wie von der Aktivität der sensorischen Eingänge (besonders des visuellen Systems), von motorischen Ausgängen, von dem Grad der intrazerebralen Verarbeitungsvorgänge, von Stoffwechselvorgängen, vom Ermüdungsgrad usw." (s.a. Beyer, Weiss, Hansen, Wolf & Seidel, 1990; Mecklinger & Bösel, 1989).

Die motorische Tätigkeit der Organismen ist von großer biologischer Bedeutung, da sie die fast einzige Form zur Verwirklichung der Wechselbeziehungen mit der Umwelt, insbesondere der aktiven Einwirkung auf diese Umwelt ist, die dadurch in einer für das Individuum nicht gleichgültigen Weise verändert wird (Bernstein, 1975, S. 141).

Dennoch sind psychophysiologische Untersuchungen des sensomotorischen Verhaltens anhand des EEGs oft so angelegt, daß die Prozesse der Informationsaufnahme und -verarbeitung (vor allem visueller Informationen) unberücksichtigt bleiben bzw. nicht exakt objektiviert werden können. Davon ausgenommen sind die Untersuchungen von Kriebitzsch (1983, 1985), Grünewald (1968), Legewie, Simonova und Creutzfeld (1969) und Ulrich und Kriebitzsch (1990), deren Ergebnisse jedoch wenig übereinstimmend sind.

Ausführlich wurde dagegen das EEG bei self-paced movements untersucht, u.a. Lang, Lang, Kornhuber, Diekmann und Kornhuber (1988), Pfurtscheller (1981), Pocock (1980), Pfurtscheller und Berghold (1989), Pfurtscheller, Lindinger und Klimesch (1986).

Die Analyse des EEGs bei repräsentativen sensomotorischen Aufgabenklassen ist nicht nur im Hochleistungssport von Interesse, sondern vor allem für die Diagnostik und Therapiekontrolle von Funktionsstörungen im sensomotorischen Bereich.

Gegenstand dieses Beitrages ist die Analyse des EEGs bei Regulation des sensomotorischen Verhaltens, das mit dem visuomotorischen Nachfolgetracking gut operationalisiert und objektiviert werden kann. Dabei hat die Versuchsperson die Aufgabe, einer auf einem Bildschirm sichtbaren Vorgabefunktion durch definierte Bewegungen so zu folgen, daß die Funktion des Nachvollzuges entsprechend der Instruktion möglichst wenig von der Vorgabe abweicht.

Fragestellung

Können die mit unterschiedlichen Trackinganforderungen verbundenen Funktionszustände des ZNSs mit der EEG-Grundaktivität erfaßt werden?

Methodik

Es wurde ein Experiment mit 12 Studenten (Vpn) im Alter von 20-25 Jahren durchgeführt. An 4 aufeinanderfolgenden Tagen fand das anforderungsmäßig gleiche Experiment statt. Die Vp saß in einem bequemen Stuhl ca. 1,20 m vom Bildschirm entfernt, auf dem die Trackingfunktionen (Vorgabe und Nachvollzug) zu sehen waren. Der Versuchsraum war abgedunkelt.

Folgende 4 Anforderungen mußten realisiert werden:

Ruhe — ruhig sitzen bei geöffneten Augen.

Sprung — Tracking "Sprung", Instruktion: "Ihre Aufgabe besteht darin, das neue Niveau so schnell wie möglich zu erreichen und stabil zu halten!"

Der Nachvollzug wurde realisiert, indem der Hebel eines Potentiometers mit den Fingern der rechten Hand hin und her bewegt wurde. Dabei lag der rechte Unterarm auf der rechten Stuhllehne.

Reaktion — Anforderung zur Messung der einfachen optischen Reaktionszeit. Instruktion: "Reagieren Sie so schnell wie möglich auf den Sprung, jedoch ohne das neue Niveau einnehmen oder stabil halten zu müssen!"

Die Anforderung "Reaktion" stellt an sich kein Tracking dar. Sie dient zur Abgrenzung einfacher Reaktionszeiteffekte von zentralnervalen Prozessen, die mit dem Nachfolgen der Sprungfunktion zusammenhängen.

Sinus — Tracking "Sinus" (0.1, 1.1 und 2.1 Hz je ca. 30 sec).

Instruktion: "Verfolgen Sie den Sinus möglichst exakt, indem Sie die Abweichung zwischen Vorgabe und Nachvollzug minimieren!"

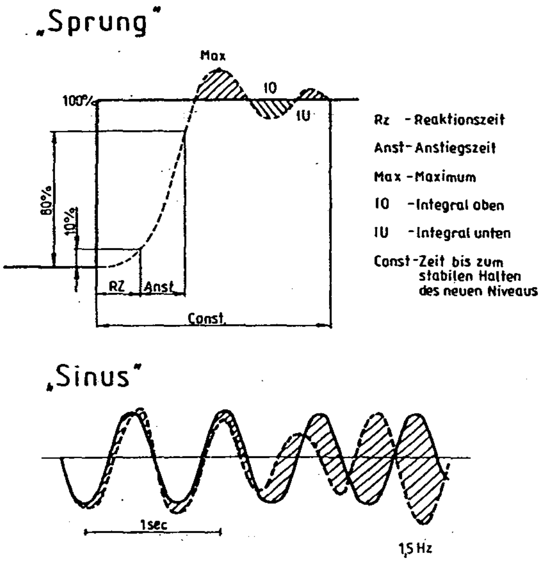

Abbildung 1. Trackingfunktionen Sprung und Sinus, Vorgabe und Nachvollzug.

EEG und Parameter

Während der Anforderungen *Ruhe* und *Sinus* wurde das EEG über je 2 mal 6,5 sec erfaßt. Beim *Sprung* und der *Reaktion* erfaßten wir das EEG im Zeitintervall 4,5 sec vor bis 2 sec nach dem Sprung bzw. der Reaktion.

Ausgewertet wurden die Zeitintervalle 4,5 sec ***vor*** der Anforderung Sprung bzw. Reaktion und 6,5 sec ***während*** der Anforderungen Ruhe und Sinus.

Das EEG wurde unipolar gegen das rechte Ohrläppchen von links frontal (F3), links zentral (C3) und links okzipital (O1) entsprechend dem 10-20-System abgeleitet. Parallel zum EEG wurde das EOG (Elektrookulogramm) des rechten Auges, die Vorgabe und der Nachvollzug des Tracking aufgezeichnet (s. Abbildung 2). Anhand des EOGs war es möglich, mit Augenartefakten behaftete EEG-Abschnitte zu eliminieren. Es wurde sichergestellt, daß jeder in die Auswertung einbezogene und von Artefakten bereinigte Meßabschnitt eine Mindestlänge von 2 sec hatte. Für die klassischen Frequenzbänder (Theta: 4-8 Hz, Alpha1: 8-10 Hz, Alpha2: 10-13 Hz, Alpha: 8-13 Hz, Beta1: 13-18 Hz) des fouriertransformierten EEG-Zeitsignals berechneten wir die Frequenzbandschwerpunkte und die mittleren Leistungen im Frequenzband.

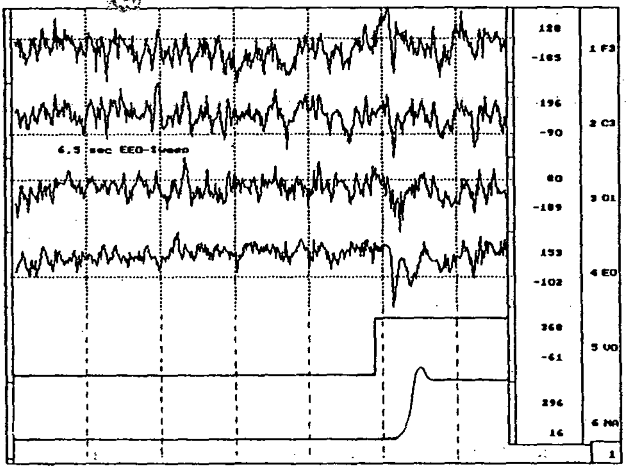

Abbildung 2. Registrierbeispiel der Aufzeichnung der drei EEG-Kanäle (F3, C3, O1), des EOG, der Vorgabe und des Nachvollzuges des Trackings (hier nur Sprung), Vp 5, 1. Versuchstag.

Ergebnis und Diskussionen

Eine Möglichkeit zum Erfassen des anforderungsbezogenen Aktivitätsniveaus des ZNSs anhand der EEG-Grundaktivität ist der Vergleich der EEG-Parameter der Ruhesituation mit den EEG-Parametern der unmittelbar darauffolgenden Anforderungssituation. Beispielhaft werden die Ergebnisse der EEG-Parameter für eine mittlere Leistung im Theta-Band (THL) und Frequenzbandschwerpunkt des Alpha-2-Bandes (A2S) vorgestellt.

Die THL (4-8 Hz) zeigt für alle Ableitpunkte eine signifikante Abnahme von der Ruhesituation zum darauffolgenden Tracking Sprung. Sehr ähnliche Ergebnisse finden Hansen, Rost, Weiss und Beyer (1991) beim Übergang von einer Ruhephase zu einer Phase mentalen Trainings, das jedoch mit geschlossenen Augen durchgeführt wurde.

Pfurtscheller und Aranibar (1978) beschreiben eine globale Abnahme der EEG-Aktivität (6-8 Hz) vor und während einer bedingten Daumenbewegung (bei geschlossenen Augen) und erklären sie "mit kortikalen Aktivierungsvorgängen als Folge der Erwartung, Antizipation, Entscheidungsfällung und Reizperzeption" (S. 23).

Bezüglich des Vergleiches der Ruhe und der Anforderung *Reaktion* kam es nur zentral (C3) zu einer Abnahme der THL. Das ist insofern interessant, da bei den Anforderungen *Sprung* und *Reaktion* im Anfang an sich gleiche Bewegungen realisiert werden. Beim Sprung müssen zusätzliche Prozesse der Informationsaufnahme und -verarbeitung ablaufen, um die zur Aufgabenbewältigung erforderliche Bewegungsgeschwindigkeit und -genauigkeit realisieren zu können. Offenbar reflektiert dieser Parameter eine spezielle Aufmerksamkeitszuwendung zur Aufnahme sensorischer Informationen (Sprung). Eine andere Interpretationsmöglichkeit wäre, daß vor dem Sprung ein umfangreicheres Bewegungsprogramm aufgebaut werden muß als vor der Anforderung Reaktion. Der Theta-Rhythmus könnte auch motivationale und intentionale Prozesse aufgrund des unterschiedlichen Niveaus der Aufgabenkomplexität widerspiegeln (Lang et al., 1988). Beim Vergleich der Ruhesituation mit dem Tracking *Sinus* zeigt sich dagegen tendeziell ein Anstieg der THL (Abbildung 3).

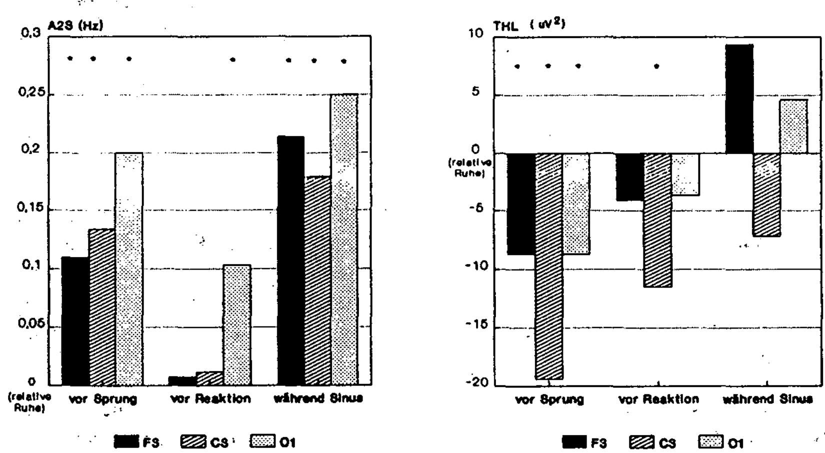

Abbildung 3. Veränderungen der EEG-Parameter A2S (10-13 Hz) und THL (4-8 Hz) von einer relativen Ruhe (geöffnete Augen) zu den Anforderungen vor Sprung, vor Reaktion und während Sinus für alle Ableitpunkte (F3, C3, O1).
* signifikante Unterschiede zwischen Ruhe und Anforderung, Irrtumswahrscheinlichkeit < 5% (Wilcoxon).

Für Sprung und Sinus erkennt man für alle Ableitpunkte eine Verschiebung des A2S (10-13 Hz) in hochfrequentere Bereiche, bezüglich der jeweils unmittelbar vorhergehenden Ruhesituation. Auch hier spielt wahrscheinlich die Problematik Bewegungskomplexität eine Rolle. Mit zunehmender Bewegungskomplexität (der Sprung ist komplexer als die Reaktion) verändert (erhöht?) sich das kortikale Aktivitätsniveau, was zentral in einer höherfrequenten EEG-Grundaktivität im Alpha-2-Frequenzband zum Ausdruck kommt. Bisher konnten solche aufgabenabhängigen Veränderungen der Hirnaktivität bereits vor der unmittelbaren Bewegungsausführung nur für Gleichspannungsänderungen und langsame Potentiale nachgewiesen werden (z.B. Pfurtscheller, 1981). Berücksichtigt man noch zusätzlich den Sinus, so scheinen sich auch im Parameter A2S Bewegungskomplexität, Informationsverarbeitungsprozesse (siehe THL) und tatsächliche Bewegungsausführung widerzuspiegeln, die hier nicht weiter differenziert werden können.

Zusammenfassung

Zusammenfassend läßt sich sagen, daß die Vorbereitung und Ausführung sensomotorischer Anforderungen mit differenzierten Funktionszuständen des ZNSs verbunden ist, die mit den hier beispielhaft vorgestellten EEG-Parametern erfaßt werden können. Wenn es gelänge, einen ähnlichen Bezug zu den Trackingleistungen herzustellen, erschiene die EEG-Grundaktivität noch besser zur Charakterisierung spezifischer Erregungszustände des ZNSs geeignet. Damit wäre ein weiterer Nachweis erbracht, daß das EEG nicht nur das allgemeine Aktivitätsniveau des ZNSs widerspiegeln kann, sondern die für die sensomotorische Regulation und Leistung relevanten Funktionszustände bzw. Aktivitätsmuster des ZNSs (Ulrich & Kriebitzsch, 1990).

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ZUR REGULATION PSYCHOMOTORISCHEN KOOPERATIONSVERHALTENS BEI UNTERSCHIEDLICHEN AUFGABENKLASSEN

OLAF POPP UND JENS WIEMER, DEUTSCHLAND

Gegenstand des Beitrages ist erstens das Problem der individuellen Bewegungsregulation in Mehrpersonenhandlungen, d.h. die Frage nach den Veränderungen individueller Ausführungsstrukturen unter sozialen Handlungsbedingungen, und zweitens die Beschreibung der Bedingungen, unter denen das Ganze mehr ist als die Summe seiner Teile, d.h. die Gruppenleistung die Summe der Einzelleistungen übersteigt. Damit ordnet es sich u.a. ein in den Problemkreis der Gruppendynamik sowie des Zusammenhangs zwischen Gruppeneffektivität und Gruppenzusammensetzung.

Von Cranach, Ochsenbein, Tschan und Kohlöer (1987) resümieren: " ... eine Gruppe ist nun mal etwas anderes als ein Individuum ...", und Singer (1985) stellt fest, daß es ein Unterschied ist, ob Lern- und Leistungsprozesse mit, gegen oder vor anderen Menschen bzw. allein realisiert werden. Dabei finden Handeln und Leisten eher in sozialen als in isolierten Situationen statt.

Entscheidenden Anteil an der Spezifik von Gruppenhandlungen tragen die in den Interaktionen entstehenden Wechselwirkungen. Diese zeigt sich in der Tatsache, daß zielgerichtetes Verhalten sozialer Systeme sich immer im Handeln von Individuen verwirklicht, aber nicht darauf reduziert werden kann. Dem *Ganzen*, dem sozialen System kommen dann auch Eigenschaften zu, die den handelnden Individuen nicht immanent sind (Hacker, 1986; Probst 1987; u.a.). Als Folge ist zu konstatieren, daß sich Gruppenleistungen nur zu einem Teil (40-60%) aus den Ergebnissen der Individualdiagnostik voraussagen lassen. Begründet wird dies mit der Entstehung einer "Gesamtkraft", einer besseren raum-zeitlichen Koordinierung von Einzelleistungen und Einzelfähigkeiten (Hiebsch & Vorwerg, 1980), mit "sozialer Erleichterung" (Zajonc, 1965, zit.n. Wankel, 1980), einer Mehrbeteiligung kognitiver Prozesse sowie der Erhöhung des allgemeinen Aktivierungsniveaus (Singer, 1985; Hacker, 1986; u.a.). Pöhlmann (1986) konnte beim Übergang vom Einzel- zum Dualvollzug sportlicher Handlungen eine Änderung in der Koordinationsstruktur, in den Orientierungsgrundlagen und der Antriebsregulation der beiden Partner feststellen. Der praktische Bezug: Personen können nicht ausschließlich nach ihren individuellen Leistungen gruppiert werden.

Neuartige Interpretationsmöglichkeiten ergeben sich im Lichte selbstorganisationstheoretischer Positionen, nichtlinearer, dynamischer System-Umwelt-Betrachtungen, die "Gleichgewichtsferne" als Voraussetzung und Ursache für Veränderung und Entwicklung ansehen. Ein Fazit aus Herman Haken's Synergetik ist die Existenz universaler Prinzipien der Verhaltensorganisation komplexer Systeme. Im Zusammenwirken der einzelnen Teile eines Systems entstehen neue räumliche, zeitliche oder funktionelle Strukturen. Es ist dabei unbedeutend, ob diese Teile Atome, chemische Verbindungen oder Individuen sind. Situationen, in denen sich das Verhalten des betrachteten Systems qualitativ ändert und eine neue Struktur bildet, beschreibt das Konzept der Ordnungsparameter in den Phasenübergängen (Versklavungsprinzip). Es erklärt die Entstehung von *Ordnung aus Chaos, von Stabilität aus Variabilität.*

Erste Belege aus dem Bereich der Bewegungskoordination sind u.a. die Untersuchungen von Kelso (1990) zur Fingerkoordination, von Turvey (1990) zum spontanen Koordinationsmuster-Wechsel bei Gliedmaßenbewegungen zweier Personen mit optischem Kontakt, die Studien zum Koordinationswechsel beim Übergang vom Gehen zum Laufen und umgekehrt von Kelso, Bunz und Haken (1985).

Die Existenz mehrerer stabiler Zustände eines Systems oder seiner Teilsysteme, die sogenannte Multistabilität, bezeichnet Pöhlmann (1991) als eine Form der Ganzheitlichkeit und motorischen Äquivalenz. Auftretende Fluktuationen, nach Jantzsch (1979) die nichtlineare Eigenverstärkung von Fluktuationen, testen laufend die Stabilität vorhandener Strukturen, was unterhalb kritischer Grenzen nicht zur Um- oder Neubildung von Strukturen führt.

Als Folge wäre zwischen der Aufwertung von Programmfehlern und einer Ablehnung von "Motorprogrammen" zu entscheiden. Ein Gedanke, der auch von Foersters (1985) Theorie der "Maschine mit endlich vielen Zuständen" zugrundeliegt.

Annahmen

Verhaltensschwankungen von Systemen in Übungs- und Wiederholungsfolgen dienen einer Selektion individuell günstiger Problemlösungen.

Für die "Systeme" Individuum und Gruppe kommt es im Prozeß der Aufgabenbewältigung zur Ausbildung spezifischer strukturell-funktionaler Beziehungen, was zur Selbstfindung temporärer, optimaler Systemstabilität unter gegebenen Anfangsbedingungen führt.

Anfangsbedingungen in Mehrpersonen-Handlungen stellen die individuellen, psychomotorischen Strategien der Gruppenmitglieder dar.

Der kooperative Bewegungsvollzug stellt in diesem Kontext eine Situation dar, in der sich das Verhalten des Systems Individuum qualitativ verändert, u.a. durch quantitative Umweltänderung.

Für diese Übergangsphase ist entscheidend, welche individuellen Ausführungsstrategien aufeinandertreffen, im Zusammenwirken die neue räumliche, zeitliche oder funktionale Struktur bilden.

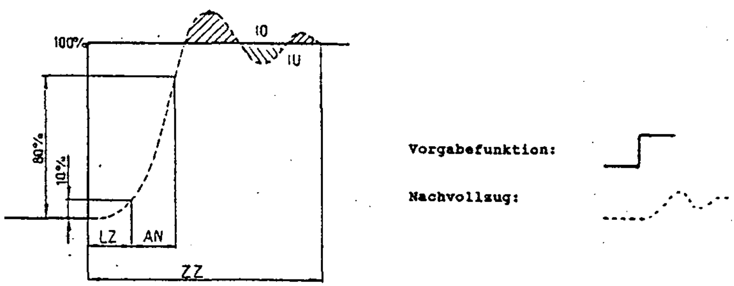
"Kooperation" auf Gesamtsystemebene schließt "Wettkampf" auf Subsystemebene nicht aus.

Die Gesamtsystemdynamik ist von der Vergangenheit der Subsysteme abhängig. Sie kann als summativ, dominant oder übersummativ bezüglich der Vergangenheit ihrer Subsysteme charakterisiert werden (siehe Abbildungen 2 bis 5).

Methodentechnik

In einer Laboruntersuchung wurden 15 Vpn und sechs Gruppen zu je drei Personen die Bewegungsaufgabe gestellt, mittels Geber einer über ein Sichtgerät vorgegebene Sprungfunktion mit dem Ziel nachzufahren, das neue Niveau so schnell und so genau wie möglich zu erreichen und stabil zu halten.

Methodentechnisch fand eine Variante des Nachfolgetrackings Anwendung. Bei den Gruppenversuchen wurden die drei Einzelleistungen über ein spezielles Interface zusammengefaßt und als einheitlicher Nachvollzug auf dem Sichtgerät ausgegeben. Folgende Parameter, von insgesamt 150 Sprüngen, wurden in einem ersten Schritt analysiert und als Merkmale der Ausführungsstruktur interpretiert.



LZ - Latenzzeit: Zeit zwischen Vorgabe und Beginn des Nachvollzuges
AZ - Anstiegszeit: Zeit für den Nachvollzug der Strecke zwischen 10% und 80% des neuen Niveaus
Iu - Integral unten: Maß für die unter der Vorgabefunktion entstehende Fläche
Io - Integral oben: Maß für die über der Vorgabefunktion entstehende Fläche
ZZ - Zielzeit: Zeitpunkt des stabilen Erreichens des oberen Niveaus

Abbildung 1. Parameter der Analyse von Sprungfunktionen.

Ausgewählte Ergebnisse

Die Abbildungen 2 und 3 zeigen den Vergleich zwischen den Ausführungsstrukturen der Gruppen 3 und 5 sowie dem Mittelwert der Ausführungsstrukturen der Gruppenmitglieder im standardisierten Merkmalsraum.

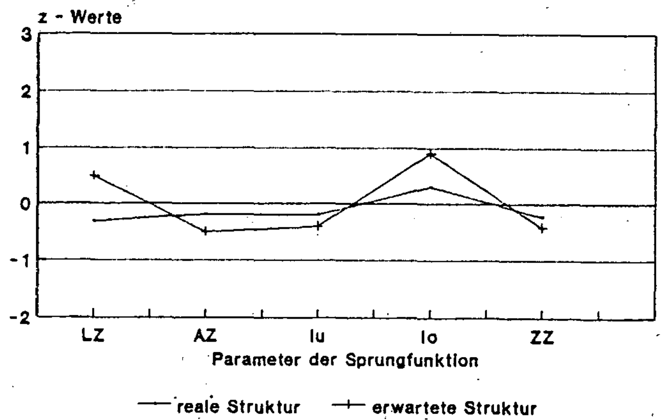


Abbildung 2. Ausführungsstruktur Gruppe 3.

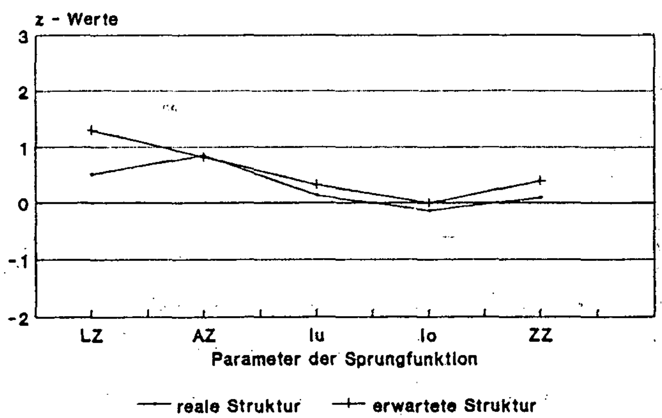


Abbildung 3. Ausführungsstruktur Gruppe 5.

Abbildungen 4 und 5 zeigen den Vergleich zwischen der realen Ausführungsstruktur der Gruppe und der Gruppenmitglieder.

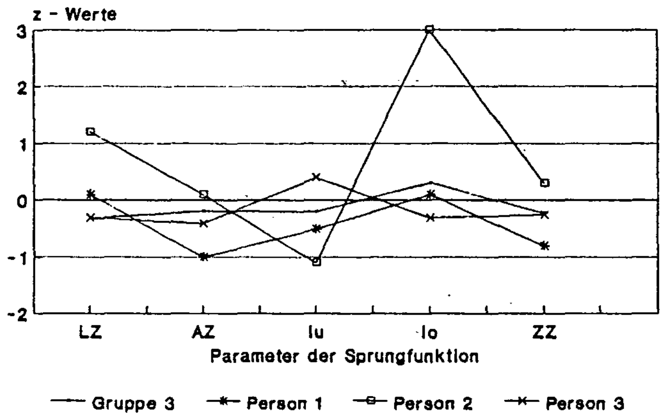


Abbildung 4. Ausführungsstrukturen der Gruppe 3 und der Gesamtmitglieder.

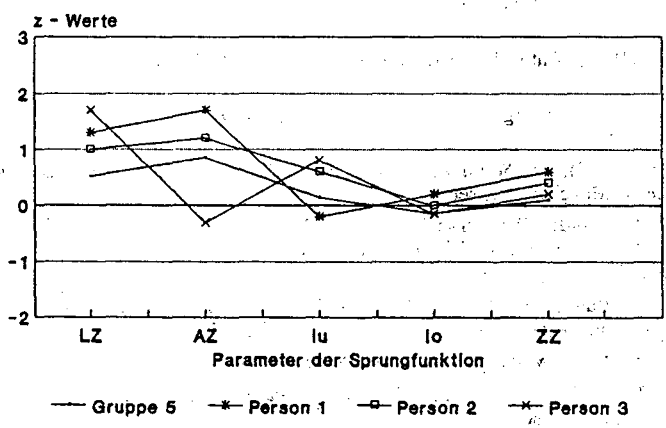


Abbildung 5. Ausführungsstrukturen der Gruppe 5 und der Gesamtmitglieder.

In Gruppe 5 besteht eine hohe Korrelation zwischen der Struktur von Person 2 (P2) und Person 1 (P1) und der Gruppe ($r=.90$, $p=.001$).

Die hohe Korrelation zwischen der Gruppenstruktur und dem Mittelwert der

Ausführungsstrukturen in Gruppe 5, r=.86 (p=.031), interpretieren wir als summative Eigenschaft der Gruppendynamik bezüglich ihrer Gruppenmitglieder.

Für Gruppe 3 besteht kein derartiger signifikanter Zusammenhang zwischen Gruppenstruktur und dem Mittelwert der Ausführungsstrukturen. Ein signifikanter Zusammenhang besteht zwischen den Ausführungsstrukturen der Gruppe 3 und von P2 (r=.87, p=.028). Die Gesamtsystemdynamik wird damit dominant von P2 beeinflußt.

Beim Vergleich aller Gruppen bzgl. des Leistungsparameters ZZ wiesen die Gruppen mit "Dominanz" tendenziell einen Vorteil gegenüber den anderen Gruppen auf, d.h. sie realisieren den stabilen Nachvollzug auf dem neuen Niveau schneller.

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2

Grundkonzepte des motorischen Lernens

Basic Concepts of Motor Learning

THE IMPORTANCE OF MODELS OF MOTOR CONTROL FOR MOTOR LEARNING

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Prefatory Remark

The content of the following paper is epistemological in character; it is about the relation between what is externally given (mapped by the human senses) and what is internally processed (the dynamics of the human mind). In the history of philosophy one can observe the tendency to reduce this relation to a directed causal relationship: For example, John Locke's empiricism bases the content of the mind (specific and general ideas) on the sensory experiences ("No man's knowledge here can go beyond his experience"); in contrast, the idealism of Bishop Berkeley sees the mental process of perceiving as the act constituting reality ("esse est percipi" to be is to be perceived). Especially modern psychology as a kind of experimental epistemology has paved the path for understanding this relationship no longer as unidirectional but bidirectional; especially Gestalt psychologists as Köhler or Koffka and J.J. Gibson as the founder of 'ecological perception' have stressed the interactive view in epistemology. It should be noted, however, that this view can already be identified in the pre-Socratic fragments of Democritus, especially when reading fragments 13 and 20 on the relation between perception and cognition or between the senses and the mind:

> "There are two kinds of experience: one is genuine and the other is not. Seeing, hearing, smelling, tasting, feeling are all subjective, they have to be distinguished from genuine experience. If the objects of perception become too small to be picked up [by the senses] and finer discrimination is necessary, then we have to take recourse to the genuine experience, namely to thinking, the most sensitive organ residing in the mind."

> "... 'Poor mind' the senses say to the mind, 'from us you have everything even what you bring forward against us. If you destroy us, you bring destruction upon yourself, too.'"

Democritus, however, confined the role of the mind to situations where the dicriminability of the senses no longer suffices, but Aristotle in his Nikomachian Ethic has generalized this point to a general epistemological principle:

> "It is the mark of an educated mind to rest satisfied with the degree of precision that the nature of the subjects admits, and not to seek exactness when only approximation is possible."

This principle can be circumscribed as the 'search for the proper level of the universal principle of science: Examples are again Gestalt psychology and Ecological psychology but also those directions in biology, chemistry, and physics which pay attention to the phenomenon of self-organization (for instance, Eigen's 'game of life', Prigogine's 'dissipative structures', and Haken's 'synergetics').

One is tempted to ask: What are the consequences of these epistemological considerations for a decidedly applied science as sport psychology? The following — still in parts speculative — ideas are intended to convince the reader that this epistemological stance has not only consequences for the experimental analysis of motor behaviour but also for the field of coaching and training. Specifically, the following topics will be discussed:

(1) Motor learning: General or content specific?

(2) the search for the motor unit,

(3) the dynamics of motor control and motor regulation,

(4) the complementarity of stability and singularity in motor learning, and

(5) the practical consequences for training and coaching.

Motor Learning: General or Content Specific?

In basic science (including psychology) one tends to discriminate between general (syntactic) theories and specific (semantic) theories. The first give the rules to work with the material of the latter. In psychology especially learning theories have been regarded as syntactic theories providing rules and regularities independent from the areas of application, e.g. Thorndike's law of effect or the theory of transfer in learning based on 'common elements' do not refer to any questions of content. This point of view has been reinforced by the apparent success one had in using the von-Neumann computer as a model for human behaviour; the distinction of programmes and data is in accordance with the distinction of rules and objects, syntax and grammar, or procedural and declarative knowledge in cognitive science.

Recent developments in parallel distributed models based on the work of McCulloch and Pitts (1943) by Hopfield, Rumelhart and McClelland, to name only a few paradigmatic researchers have cast doubt on the necessity (as claimed by Chomsky, 1971) and on the viability approach of this dualist approach [1] as

[1] In Gestalt theory this distinction has never been made and it is therefore no surprise that Hopfield speaks of 'Gestalten' as emerging from his neural network model due to parallel processing and that McCulloch models the universal quantifier by an averaging process, the same which has been postulated for the 'evolution of good forms'.

postulated by artificial intelligence.

For these reasons, it seems necessary to investigate the interdependencies between rules of learning and the content of learning and to ask if not unified approaches are necessary. Here I present some very preliminary ideas and reappraisals of more traditional approaches to motor learning and I will argue that they fit into what we know about motor control and athletic performance.

One reason why the necessity for unified theories in motor learning has been disregarded is that such theories cannot be algorithmic, the other reason is that one has been preoccupied with simple motor acts as the building blocks.

The phenomenon of complex motor performance has a curious status in psychology: From the point of view of methodology it should be avoided because on higher levels of complexity most of the assumptions underlying statistical analysis are not valid, on the other hand its very analysis might provide unique insights into the processes underlying motor behaviour. Up to date most experimental studies of motor behaviour for these reasons have stuck to simple movement patterns for which the data conform very well to the linear models of classical statistical analysis and it has been implicitly assumed that complex motor behaviour including peak performance consists in a combination of simple motor patterns as fingertapping, pointing, or aiming. Following this line of argumentation, the same rules governing the acquisition of any simple motor behaviour are also applicable to any more complex motor patterns. However, as Zimmer (1990) has shown, this implicit assumption of linearity is not even given in the acquisition of a moderately complex motor skill (see Table 1). This table shows how performance parameters for riding a pedalo change during the learning process and that these changes are not linear.

The non-linearity in the results of Table 1 have two theoretically important implications:

(1) They cannot be accounted for by models that understand learning as the summation of elementary conditioned reactions (as, for instance, in stimulus-sampling theory) or as consisting of independent building blocks which are added in a piecemeal fashion, albeit obeying the constraints of a given 'architecture of cognition' (Rumelhart & Ortony, 1981) because they would imply a general decrease in the variability of the performance.

(2) They make necessary the assumption of — at least — two points of stability in the performance landscape (or two minima in an energy landscape as in Figure 1) towards which the performances organizes itself. In order to give up the stable — albeit ineffective — pattern of the beginner it is necessary to move through a phase of increased variability, that is, less stability before another — more effective — pattern of selforganized behaviour can be attained.

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Table 1. Change of performance parameters for riding a pedalo during the learning process.

		performance level						
		low		intermediate				high
physical data		(A)		(B)				(C)
effective	mean	A	≈	B	B	>>		C
forces	variability	A	>>	B	B	≈		C
directional	net amount	A	<	B	B	>		C
changes	smoothness	A	<<	B	B	<		C

<: $p<0.05$, <<: $p<0.01$

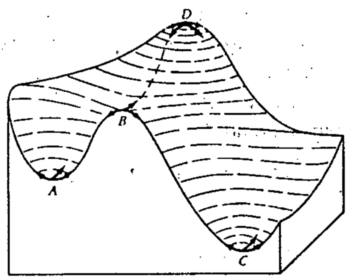

Figure 1. A potential landscape with maxima and minima.

In Figure 1 such a situation with two minima is modelled where only the introduction of critical fluctuations can result in the switching from one stable position to the other. These critical fluctuations can be introduced from the outside. For instance, Zimmer and Körndle (1990) have used a rough and irregular surface of the floor in order to support a stable coordination for riding the pedalo with a slow speed. Such critical fluctuations can arise from the interaction of the affordances of the environment (what modes of action it allows) and of the motor units as most simple actions which can be produced intentionally or triggered by external stimuli — as it is done explicitly or implicitly in most behaviouristic accounts for motor skills. The alternative consists in defining motor units as minimal motor patterns exhibiting self-organization, that is, a tendency towards stable coordination.

In Search of Motor Units

Traditional definitions of terms concerning motor behaviour are based towards anatomy (for instance, Tomovic & Bellmann's [1970] treatment of degrees of freedom in the human body or Hanavan's [1964] model) or — at least — towards biomechanics and not towards biocybernetics. This has not only narrowed down the scope of research in motor behaviour but it might also be the case that one has — perhaps only partially — missed the proper level of analysis and thereby produced artifacts.

What are elementary motor actions (or units of motor behaviour) cannot be determined from biomechanical constraints only because the decisive criteria are invariance and self-organization of action. Insofar walking despite its apparent complexity seems to be a basic unit, a schema of motor action, but perhaps not the seemingly simpler positioning tasks or finger tapping. This might explain why Schmidt's theory of schemata seems to fail Stelmach and Diggles' (1982) criterium of motor invariance, not because of its too general approach but because of the fact that it is investigated in too simple forms of motor behaviour which are below the level of a fullfledged motor schemata.

Furthermore, if self-organization and invariance are the core features of schemata as building blocks of motor action, then the criteria of Stelmach and Diggles (1982) for theories of motor learning become incorporated into what defines a motor unit, namely,

(a) the synergistic reduction of complexity (in the sense of Haken, 1991) where finally one order parameter determines the resulting motor behavior (Bernstein's problem of degrees of freedom disappears if stated this way),

(b) the invariance of temporal and spatial relations which is due to the fact that a motor unit is only specified up to admissible transformations, that is, the potential landscape, which defines the motor unit in terms of synergetics, is scale invariant,

(c) motor equivalence, according to which one motor action can be produced by biomechanically different patterns of coordination, can be understood as the result of the fact that one and the same control parameter can be the result of differing realizations of self organization. One consequence of this view is that motor units are characterized among other features by the fact that its parts can exhibit more variability than the whole unit itself for an example.

The consequences of these results are twofold: The question of what constitutes a unit of motor behaviour becomes the central problem of motor learning and since these units do not coincide with the anatomical and bio-mechanical units, one has to discriminate between the control level (the governing level according to Bernstein, 1967) including its order parameter(s) (Haken, 1991) and the regulatory levels which are 'enslaved' by the order parameter(s). This distinction has immediate consequences for the definition of automated behavior, for the relation between peak and 'normal' performances, and for the question what really constitutes and uphelds peak performances.

The Dynamics of Motor Control and Motor Regulation

The classical reconstruction in biomechanics of the human body as rigid segments connected by joints and moved by muscles characterized by fixed physical parameters (Hanavan, 1964) disregards not only the fact that from a biocybernetical point of view it is more efficiently regarded as visco-elastic (Nelson, 1983) but it furthermore implies the baffling question how such a complex system can be controlled: Bernstein's problem of the degrees of freedom. Statistical analyses of the correlations between the centers of gravity of body segments (e.g. Schöllhorn's [1990] biomechanics of disc throwing) result in a reduction of complexity, that is, few factors "explain" a high percentage of variance, but multivariate statistical models are linear in nature and therefore cannot be used to analyze a phenomenon as motor behaviour because of its intrinsic non-linearity, for instance, the relations between speed and kinetic energy or time-to-contact and distance-to-contact. Also the alternative suggested by the MIT-school (Hollerbach and others) that controlling motor behavior is equivalent with computing the inverse kinematics of the task in question does not lead to the reduction in complexity which is necessitated by the constraints of the human mind, especially of the human working memory. A viable solution might be provided by the distinction between control and regulation as in ergonomics, where control consists in the setting and supervising of gross parameters for the process in question, while at the same time negative-feedback systems like servo-mechanisms or timers (e.g. oscillators) result in the smooth and easily manageable behaviour of the to-be-controlled process. Similarly, the 'plan' for a motor action including the intentional goal setting and evaluation can be implemented by the specific triggering of self-organizing sub-processes as Gallistel (1980) describes them; what is important to keep in mind here that these sub-processes are not intentionally controlled but organize themselves.

Why it is necessary to assume that motor coordination depends — at least — on two components, namely control and regulation, the following anecdote brings home: A centipede when asked how he managed to control all his feet, said: "Gee, never thought about it" and henceforward was not able to walk again. Similarly, the conscious control of the more than 700 degrees, as Tomovic and Bellmann (1970) counted them, obviously transgresses the capacity of the short term memory and is therefore not viable. On the other hand the human creativity in producing motor patterns seems unbounded and a huge amount of motions, manipulations, and gesticulation are intentional actions. For these reasons, already in very early, mostly clinical studies of motor behaviour one finds the assumption of the dual character of motor coordination.

Already Liepmann (1905, p. 47) indicates that control and regulation are not only conceptually different but can also be independently impaired, that is, can be functionally dissociated. He describes the case of an unilateral apraxia where the patient was able to perform a task with the left but not with the right hand:

"He possesses everything about the action what is communicable, objective, and for everybody else perceivable. What is missing, namely the ability to move his right arm in the described way, is something not communicable, which cannot become the object of another's consciousness, it is the ability to perform, not the knowledge, and that is a function of the nervous level and perhaps of the theoretically assumed imagery of it: The remembrance of the sensations accompanying the performance of the right hand [before the apraxia], something which cannot be communicated adequately (the so called kinesthetic imagination)".

What Liepmann called the movement formula (Bewegungsformel), namely what is communicable about a motor action, resembles very much the concept of a motor programme (Pew, 1966) or the memory trace according to Schmidt (1975) whereas the 'ability to perform' or the 'kinesthetic imagination' reminds of the 'perceptual trace' or of the servo mechanisms assumed to complement the motor programme.

A closer inspection of Liepmann's analyses reveals that his distinction of the 'movement formula' and the kinesthetic imagination is captured best by the distinction between the propositional and the analogue memory, he writes "the 'movement formula' maps the composition, the structure of the movement, it defines uniquely the action, independently from the sensory representation of the 'movement formula' ..." (p. 45). If one now takes into account the results of Baddeley (1976) according to whom the kinesthetic memory decays in a few seconds, and of Freyd and Johnson (1987) who have shown that the implicit dynamic of a percept (the 'representational momentum') vanishes in less than a second, one has on the one hand a very rich sensory representation with a very fast decay rate and on the other hand a very abstract representation (the 'movement formula') which is furthermore intersubjectively shareable. What remains an open question, however, is how these memory systems are related and how they produce motor actions. The model suggested by Kosslyn (1980) does not answer these questions because it regards imagery (the visual analogue representational system) as only embellishing the propositional memory albeit being a representational format in its own right, that is, organized according to rules which cannot be reduced to the rules governing the propositional representation. If one regards only the aspect of memory for actions, one misses the most important point, namely how are motor actions produced and coordinated. Any model, however, for the generation of motor action has to take into account the dual representation underlying it. If one distinguishes control, that is, the intentional generation of an action and regulation, that is, the maintaining of the action taking care of external perturbations via negative feedback and other related techniques, one has exactly a structure of coordination into which the discussed memory systems can be integrated: The control depends on the propositional plan (here regarded as equivalent with Liepmann's 'movement formula') and the regulation is based upon the perceptual input which is held active for the time necessary in the analogue representation, that does not need to be merely kinesthetic as Liepmann assumed. There remain a couple of open questions: (a) Is such a distinction more than conceptual, that is, is a concrete realization possible? (b) If by this distinction the centipede problem can be resolved, how can the complexity in planning be handled? and finally (c) What is the relation of this conception to other approaches in movement science, for instance, Schmidt's schema theory?

Gassendi (1658) has equated understanding a process with being able to build a machine that produces this process. For many problems in motor behaviour such a machine exists already since long ago: The marionette. From a Gestalt theoretic point of view modelling motor behaviour as a sequence of elementary acts or as a set of to-be-controlled degrees of freedom leads to a merely additive interpretation. The concept of a behavioural field, in contrast, implies massive interactions between the constituents which tend to a structured whole under the influence of the minimum principle. At the first glance, it seems to run counter the Gestalt psychological reasoning with its contempt for 'machine theories' to analyze the behaviour of a marionette in order to identify the functional principles of motor behaviour but a closer inspection will show that a marionette, albeit a machine is not a clockwork which Gestalt psychologists attacking machine theories had in mind but an assembly of non-rigidly interacting parts which — for instance — get organized into the structured tempo-spatial pattern of walking. The seemingly complex behaviour of the marionettes is controlled by very few and simple hand movements of the puppeteer. The apparent complexity results from the oscillations of the limbs coordinated by the strings. The pendulum-like limbs together with the strings exhibit phenomena of selforganizing local regulation due to the fact that they are not fixed like a Newtonian clock work. The idea to fall back on the marionette when explaining motor behaviour is not new: Already 1810 F. v. Kleist analyzed human motor behaviour by comparing it with the behaviour of marionettes (Das Marionettentheater in "Berliner Abendblätter") ... "every movement (of marionettes) [has] its center of gravity; it [is] sufficient to govern this ...; the limbs, being merely pendula, follow mechanically without further intervention." Except for the not quite exact notion of 'center of gravity' this quote describes exactly the physics of a moving system where the number of degrees of freedom have been extremely reduced, in Kleist's example to one (linear motion) or two (circular or elliptical motion).

The phenomena Bernstein (1967) observed concerning the interaction of smoothness in motion without conscious control are also investigated by Kleist: "...as much as in the organic world reflexion recedes and is obscured, gracefulness becomes more brilliant and dominant..." He explains this as follows: Conscious control of motion forces the 'soul' of the moving agent away from the center of gravity of the motion. Translated into modern parlance this is equivalent to an increase in the number of degrees of freedom due to conscious control.

That motor behaviour is controlled by functional degrees of freedom and that these do not necessitate mentalistic assumptions but are as physical as the anatomic or muscular degrees of freedom can be shown by analyzing the behaviour of the marionette in Figures 2a and 2b. They show the complex walking movement of a Pinocchio marionette and how this is brought upon by one degree of freedom of the controlling hand. The coordinated movement pattern of legs and arms as natural for human walking (see Farfel, 1977) is controlled only by the oscillatory movement of the handle. This oscillator understood as in Gallistel (1980) but not misinterpreted as a pendulum in Turvey, Rosenblum, Schmidt and Kugler (1986) has one degree of freedom — acceleration and deceleration of walk is realized by damping the oscillation.

The oscillator underlying the human gait exhibits features of selforganization as can be seen in Figure 3 where in an idealized form are shown the efficiency curves of walking vs. running and the hysteresis of the process. Insofar, it is possible to identify walking and running as motor 'Gestalten', namely, modules of motor selforganization.

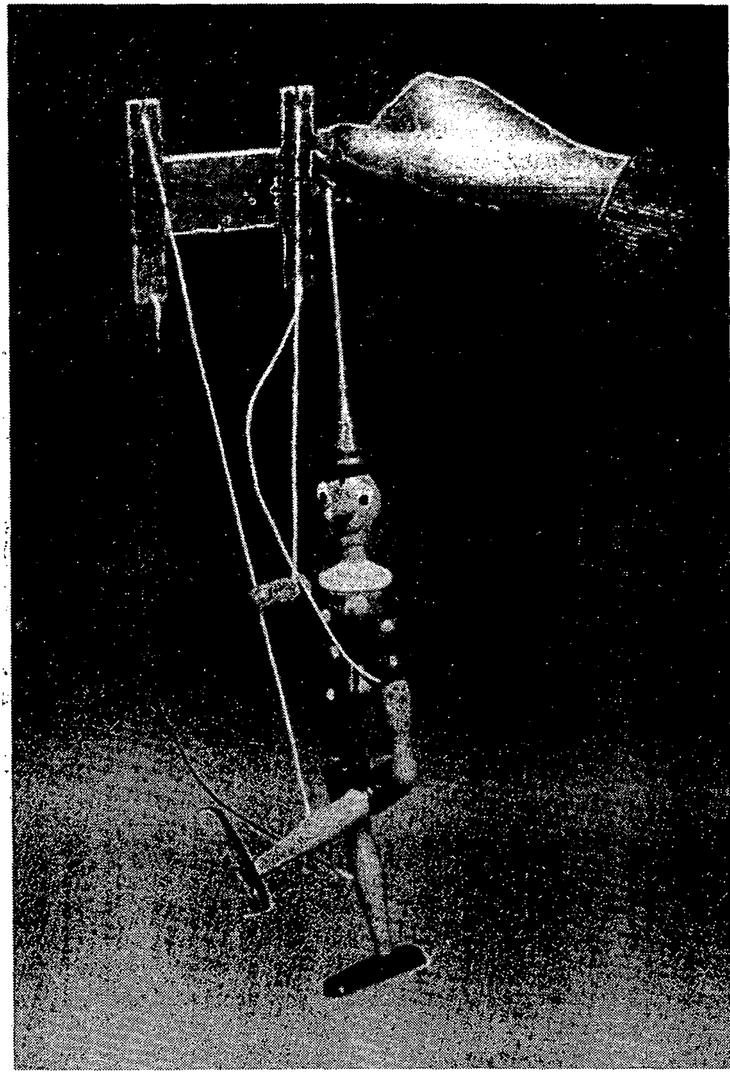

Figure 2a. Behaviour of a marionette controlled by simple hand movements.

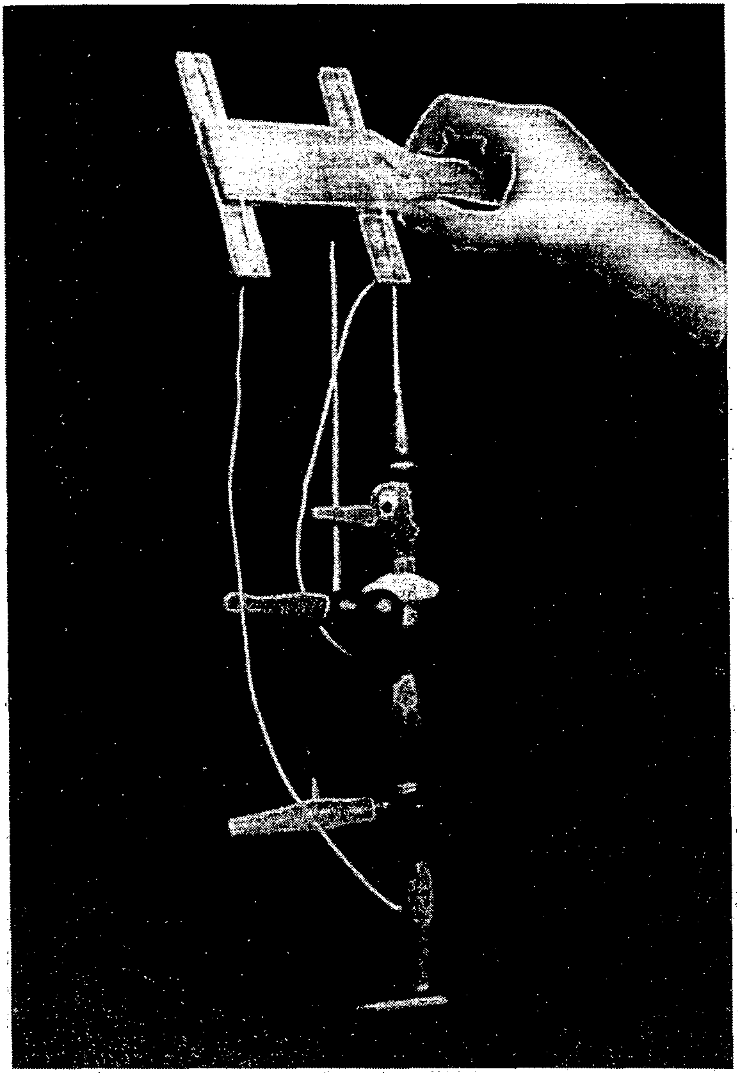

Figure 2b. Behaviour of a marionette controlled by simple hand movements.

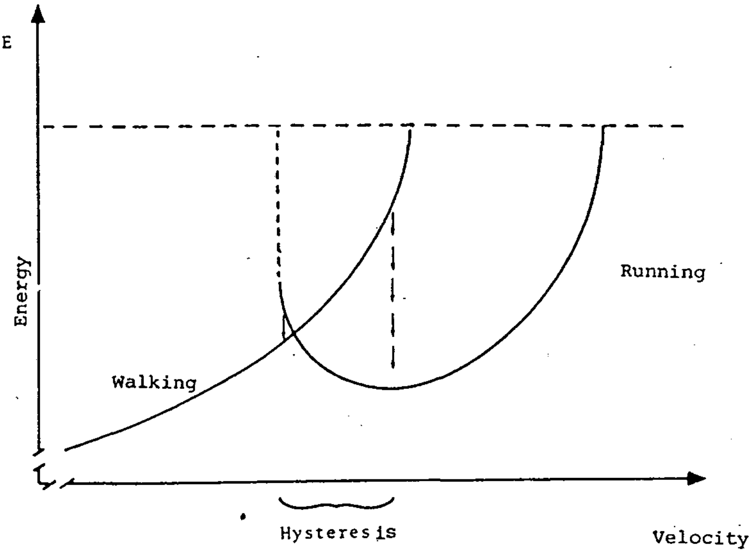

Figure 3. Phase transitions of human walking vs. running and the hysteresis of the process.

A motor Gestalt defined this way is characterized as a point of stability in a potential landscape, this position of minimal effort governed by one degree of freedom is equivalent with the case in synergetics where all but one order parameter tends toward zero.

Even if fairly complex motor actions as walking can be modelled by the marionette which produces this behaviour under the control of only one parameter and thereby providing a solution for Bernstein's (1967) problem of the degrees of freedom: The string structure of the marionette is a coordinative structure, the question remains how heterarchies, hierarchies, or sequences of motor actions can be controlled. The cognitivist approach of Hollerbach and the MIT school of motor control suggests that planning for such a behaviour consists in computing the inverse kinematics of the task. Even if one attributes a lot of smart mechanisms (Runeson, 1977) or ratiomorph heuristics (Brunswick, 1952) to the moving organism it seems questionable that it is possible to know in advance the entire kinematic landscape describing the task and to compute the complete optimal inverse kinematics for the solution before the first step is done. An equally extreme solution is suggested by Ecological psychologists as, for example, Turvey, Carello and Kim (1990) describing the behaviour of his 'happy gazelle' that does not plan at all but only optimizes situationally the affordance-effectivity coupling. Attractive as this solution is for its seeming simplicity (seeming because there is no standard procedure for determining either affordances nor effectivities), it fails for novel tasks, for instance, the Fosbury flop should not have been invented according to this approach because the globally optimal action is not the result of locally optimal affordance effectivity couplings. A solution might consist in what Hayes-Roth and Hayes-Roth (1979) have termed 'opportunistic planning': it combines the notion of the goal as a global attractor (Wertheimer's 'pull towards the goal') with the concept of many distributed heuristics making use of local optimization. That these local optimizations can induce a behaviour directed towards the goal of the task is due to the assumption that the goal influences the one weights increasing those related to motor behaviour which diminishes the distance to the goal and decreasing all others. This model can be realized in an associative net which exhibits certain Gestaltist features, namely it works like a field, more exactly like a gravitational field for which Goldmeier (1937) and Zimmer (1982) have shown that it models optimization process in perception.

The analyses of control and regulation presented so far can be integrated into the concept of schema as developed by Cassirer (1944) who integrates the Kantian notion of a schema as the cognitive mechanism coordinating sensory data and abstract concepts with the results of Gestalt psychological experiments in perception.

According to Cassirer a schema consists of

(1) constituting (basal) elements,

(2) rules of organization, and

(3) admissible transformations.

Schema theorists like Head (the first to apply this concept to motor behaviour in 1920), Bartlett (1932) and Schmidt (1975), to name only those researchers who have analyzed motor behaviour, have concentrated on the third point, that is, the question of invariance. The first point has been regarded as a question of convenience for the researcher allowing Bartlett to analyze something complex as tennis and Schmidt to concentrate on quite simple actions like pointing and other seemingly simple movement patterns.

However, as shown in the preceding part, the question of what constitutes a basic unit is far from simple and not independent from the other points. If one interprets the 'rules of organization' in a Gestaltist tradition (for a modern treatment see the book edited by Kubovy & Pomerantz, 1981), they are equivalent with Köhler's (1920, p. 250) 'minimum principle' which — applied to motor behaviour — resembles the minimum-jerkiness principle postulated by Nelson (1983) and experimentally analyzed by Wann, Nimmo-Smith and Wing (1988). This principle apparently induces motor behaviour that is subjectively experienced as "just fitting" and — seen from outside — gives the impression of effortless gracefulness.

Such a principle induces organization without an external agent and independent from a hierarchical control. Due to the fact that the constituting units of motor behaviour are not static — as the experimental and theoretical studies on schema integration show (Zimmer & Körndle, 1988) — and that their integration is usually not reversible it is no longer possible to equate a schema with the concept of an algebraic group as Cassirer (1944) did it; instead we have a situation which is modelled best with the methods of synergetics: A self-organizing regulation that nevertheless is modifiable by the induction of critical fluctuations or a change in the set of order parameters. On this background, the third constituent of Cassirer's schema theory becomes a necessary consequence of the differentiation between the level of self-organization (the necessary but noncommunicable sense-data driven regulation already present in Liepmann's [1905] theory) and the control level where the parameters are set which define the sequencing and relative timing whereas the absolute timing depends on the regulatory level. The functional independence of control and regulation becomes especially apparent in the problem of sequencing and timing because the order of intended actions and successfully executed task need not to coincide with the order of movements on the regulatory level as the data of Gentner, Grudin and Conway (1980) on typewriting show. What happens on this level is the optimisation of the spatio-temporal order of finger movement under the constraint that the rhythm of hitting the keys is kept constant. For instance, when typing the sentence 'she is piqued' the targeting movement of the left little finger for the key 'q' starts before the right index finger hits the 'i'; this is due to the fact that the little finger has to move from its home position upward and left whereas the index finger is already on the target position (see Figure 4).

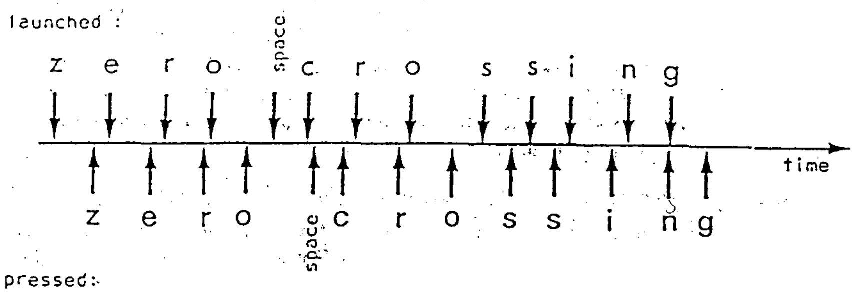

Figure 4: Time coordination of launching finger movements and hitting the keys of the typewriter (adapted from Gentner, Grudin & Conway, 1980).

Rumelhart and McClelland (1986) have modelled this phenomenon in a neuronal network and argue that it proves the entire motor behaviour to be controlled in parallel. What it really shows, however, is that between the sequential intention and the corresponding successful execution the self-organizing regulation might be best modelled as an associative network functioning in parallel.

As these results show the internal structure of the schema appears to be strictly only hierarchical: The control level influences the regulation but not vice versa. However, Lewin's (1926) experiments on psychical 'satiation' reveal that also the regulatory level can interfere with the control of motor action.

Lewin and his co-workers have observed this phenomenon in fairly complex tasks like drawing hexagons. It turns out that this phenomenon cannot be explained on the peripheral nervous level by adaptation due to inhibition or fatigue because it happens even if the biomechanics are altered by varying the length of the pencil or the form of the grip. If such a complex motor act can be 'satiated', that is, its execution be inhibited by repetition is has to be assumed that it forms a unit of the central processing in motor control resembling phenomena in speech production like spoonerism ("Schüttelreim") where the motor control in the production of complex phonetic units is severely impaired if the same or even a similar phonetic unit has to be repeated some-times.

If a complex motor pattern after multiple repetitions without external feedback breaks down, one can assume that initially it had been controlled by one order parameter, but run out of control when the local fluctuations became correlated and increased in magnitude.

The Complementarity of Stability and Singularity in Motor Learning

In the context of self-organizing regulation of motor behaviour the notion of stability as due to a minimization is central. This is especially convincing in the case of automated motor behaviour.

Traditionally, a movement pattern is classified as automatic if its performance does not need attentional capacity demonstrated by dual-task experiments. Following the theoretical framework developed here, a movement pattern is regarded as automatic if its regulation does not interfere with its control (as in Navon & Gopher's [1979] example of the interference of two apparently automated hand movements). This, however, can only be the case in a certain 'window of stability', that is, at a neither too slow nor a too fast speed: Below, the performance becomes stochastic (bursts of controlled action followed by sudden uncontrolled movement patterns) and above it becomes chaotic (that is, dependent on even minuscule changes in the initial conditions). The difference between an expert athlete and a beginner in this view consists in the size of the window of stability, that is, the amount of variability which can be regulated without a change in the parameters governing the control level (Bernstein's 'governing level') — the beginner, too, will exhibit 'automated' behaviour but only under fortuitous conditions. These conditions to identify is the goal of expert coaching because starting from there leads to the graceful performance Bernstein (1967) has observed in movement patterns not needing conscious control.

However, beside these motor actions without conscious control which can especially be found in athletic disciplines characterized by motor behaviour that mostly consists of the refined performance of motor patterns already in our motor repertory, there are disciplines (e.g. gymnastics but also in track and field) where peak performance is only possible when more than one order parameter are kept at a constant non-zero value, that is, when instead of selforganization a regulatory structure is imposed. Such a situation is usually characterized by the phenomenon that the athlete knows immediately, that is, before the motor pattern (e.g. the Fosbury flop) is finished, if the attempt will be successful or not, that is, minor perturbations are picked up — probably kinesthetically — and are perceived as significantly different from the intended structure, even if this cannot be observed from outside or exactly put into words by the athlete. On the other hand, the athlete's concept of a motor pattern, that is, what is stored in the mental representation is the imposed structure in its pure, that is, unperturbed form.

The stable mental representation, however, does not suffice for the unique determination of the execution necessary for a peak performance. For this, very specific external cues have to be provided in order to guarantee that the motor behaviour is started in the correct position and with the necessary acceleration, that is, the specification of a singularity; an example for such external cuing is the marking of the starting position in wide jump.

For the character of the mental representation of motor behaviour this implies that the representations on the control level and on the regulatory level form a complementarity of stability and singularity. This relation has two aspects:

(1) What is a singular act in a purely perceptual task (e.g. if even minor perturbations are detected without effort) turns out to be stable in a memory task. Paradigmatic experiments among many others for this aspect of complementarity have been conducted by Stadler, Stegagno and Trombini (1979) showing the sensitivity of highly regular objects to perturbations and by Zimmer (1982) expanding Goldmeier's gravitational model of 'Prägnanz' which can account for the fact that in the mental representation the distances to and from objects exhibiting Prägnanz are not symmetric.

(2) The second aspect of the complementarity, namely that of interaction between local vs. global optimization, can best be exemplified in the field of spatial

perception where the forked effect of local optimization (stability leading to the transformation of ellipses into circles, of arbitrary rectangles into squares etc.) and the uniqueness (singularity) of the point of view give rise to a stable image of the surrounding world despite the fact that any given projection can originate from a multitude of spatial arrangements. One prediction from this assumption that it is the tension between a global tendency towards stability and the sensitivity to local disturbances which generates the impression of space, is that this impression should be strongest if the forked effects are about equal.

Haken (1991) in his theory of synergetics models the complementarity of singularity and stability in a potential landscape defined by two order parameters (see Figure 5), where points of stability (minima) result when in a combination of order parameters all but one become zero. Points of singularity are the result of 'freezing' more than one order parameter at fixed non-zero values considerable larger than the turbulences in the system. This describes perfectly the singularity aspect of 'Prägnanz' as shown in the experiments by Stadler, Stegagno and Trombini (1979). By switching the signs of the ordinate in Figure 5a one gets the complementary potential landscape (Figure 5b), modelling the situation where the stability aspect prevails.

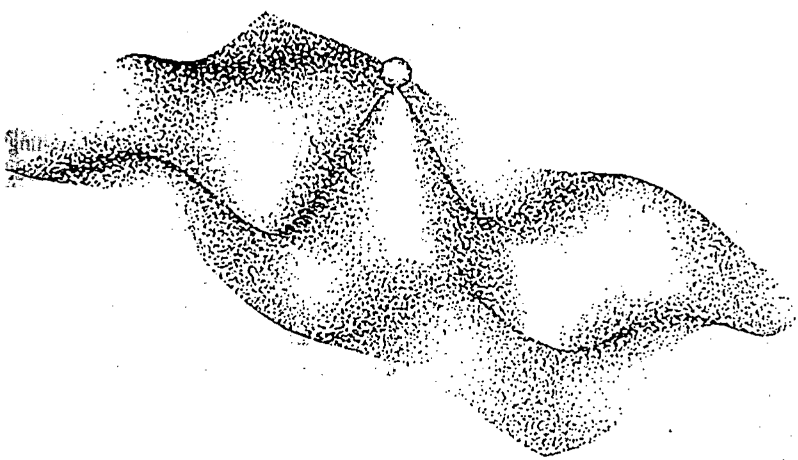

Figure 5a. Example of a potential landscape in a space of two order parameters (after Haken, 1991).

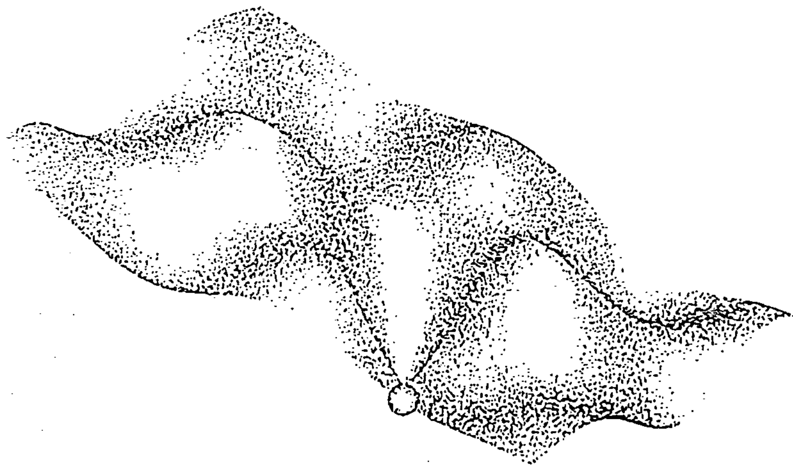

Figure 5b. A potential landscape complementary to that of Figure 5b.

Consequences for Training and Coaching

The theoretically motivated investigations into the interactions of control and regulation in motor performance have also immediate consequences for the training and coaching in diverse athletic disciplines. As most interesting I want to single out the principle of 'variability in practice' and the classifications of athletic discipline according to the underlying modes of control: Stability vs. singularity.

'Variability in practice' has been regarded as an important technique in training since long. In the context of the theoretical considerations developed above it is possible to specify more precisely under which conditions and for what goals this technique should be applied. Figure 1 shows a potential landscape with two minima, that is, points of stability towards which the motor coordination tends in the process of self-organization. If the goal of coaching consists in the acquisition of two or more alternative available patterns or if the alternative self organizing patterns of coordination differ in effectivity, variability in performance can produce those critical fluctuations in coordination that are able to induce the change from one point of stability to another. However, if coordinative patterns are regarded as layered with one control or governing level and different levels of regulation, variability in performance can be expected to 'widen the windows of stability' for controlled coordination, that is, to make the control level more stable by improving the self-organization on the regulatory levels. This results in a more effective compensation for fluctuations. Therefore even stronger fluctuations do not become critical for control and thereby causing a breakdown in coordination.

Also the juxtaposition of stability and singularity in motor control has important consequences for coaching. In completion sports especially in track and field one can distinguish between disciplines in which repetitions are allowed but where peak performances are only possible for very specific, that is, singular patterns of control (short put, high jump, javlin throwing etc.) and disciplines with only one decisive attempt but allowing compensatory coping for external perturbations and internal fluctuations (especially running, perhaps except for sprints, skiing etc.). A high level of performance in disciplines characterised by singularity can only be upheld if *permanent external feedback* is given by a coach or a technical fast-feedback system. Although most athletes very early 'sense' the failure of an attempt when motor coordination is not optimal, they are usually neither able to compensate during the attempt nor to pinpoint the cause for the failure after the attempt exactly enough to optimize the coordination permanently. Here it is the task of the coach to identfy non-optimal patterns of coordination and to induce the optimal patterns by permanent feedback (as fast as possible because the — in this kind of coordination — decisive kinesthetic memory has only a duration of about 10 seconds) by setting external constraints and, finally, by providing the athletes with mnemotechnics for the sequencing of particular acts combined with an enhancement of the sensory information processing of tension and duration in order to achieve a coordination of forces in sequence and time.

The task of a coach in disciplines characterized by self-organization towards a stable coordination is different: Except for teaching principles of tactics in competition and of compensation, it mainly consists in helping the athlete to find the optimal pattern among the perhaps many stable coordinative patterns. It should be mentioned that the 'flow experience' (Csikzentmihaly, 1990) describes the phenomenal subjective side of this process of self-organization, what the another neglects, however, is the fact that self-organisation usually is not a unique and even process but that perhaps in the majority of cases multiple local minima can act as attractors and that in such cases the optimum can only be approached by inducing 'critical fluctuations' combined with external feedback during this phase.

A special case is given if in the same athletic discipline either the aspect of singularity or that of stability can be stressed; an example is rowing a skiff where the analysis by Körndle (1989) of two world class rowers' respective coordinations of forces shows this possibility. A rower with a singularity coordination will be especially successful under fairweather conditions (and in this case actually is) but will have a hard time to compensate for stronger perturbations, in contrast, the stability coordination allows the adaptation to different turbulent water conditions without a deterioration of the performance. The 'cost' of the stability coordination lies in control: While for singularity the control is relatively simple and on a high level, for a 'stability coordination' the control level is deeper and in any case the control is more complex. This explains the superiority of the singularity coordination for weather and competition conditions where no compensation for perturbations is necessary, given the same physical condition.

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Skill Learning and Performance: New Directions

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The interest in human skills has been an integral part of the formal study of psychology since before the turn of the century. This interest, in part, is a consequence of the fact that the outcomes of skilled performance are clearly observable and hence to some extent measurable. Indeed it is this appreciation of the beauty, harmony and elegance of the skilled performer which provides the starting point for the systematic study of human skills. We can all recognize the skilled performer, we can appreciate the difference between the expert and the novice, although we may find it difficult to differentiate between the expert and the novice, although we may find it difficult to differentiate between experts themselves. However, international judges in gymnastics, diving and the like can make these judgements with great precision and consistency — their observational skills match the performance skills of the athletes!

The particular interest in human skill for the sport psychologist is that we are directly concerned with understanding, and facilitating skilled performance. In particular we are interested in maximizing the potential of the individual athlete.

Are all Skills the Same?

The diversity of the types and categories of human skills raises a theoretically crucial issue — that is, are all skills fundamentally the same?

One of the pioneers of skills research, Bartlett (1947) suggested that all skills are fundamentally the same and accord to common structural and functional principles "...all skills are learnt and can vary from being essentially 'mental' to essentially 'motor' in nature, but all of which involve several receptor and effector functions linked to achieve a particular goal or outcome"(Bartlett, 1947). This view was supported by Fitts (1964) "...since the processes which underlie skilled perceptual-motor performances are very similar to those which underlie language behavior as well as those which are involved in problem-solving and concept formation, we should expect to find that the laws of learning are also similar and that no advantage would result from treating motor and verbal learning as separate topcs" (Fitts, 1964, p. 243).

This position, of the commonality of all skills has been more recently supported by Anderson (1982; 1987) and Mackay (1982; 1987), in their systematic study of cognitive skills.

We will argue that this commonality of all skills is based upon the manner in which information, knowledge and knowledge structures accord to common principles.

The Nature of Expertise

As a first step in understanding the nature of human skill and the development of competence and expertise, we must be able to describe the characteristics of such expert performance. What are the characteristics of such expertise exemplified by the competence of the skilled performer?

Skills are Highly Organised

Skills are highly organised both spatially and temporally, that is everything about the skilled performance is systematic, serial and well-ordered. All of the aspects of the skill, all of the components or sub-components, are highly structured and organised. This organisation is typified by a number of significant features; the performance is smooth, fluent with one part of the skill flowing easily into the next phase or aspect; there seems to be a minimum of effort with no extraneous or unwanted movements, there is an integration and harmony of the movements of the body and implement (racquet) with the changing environmental contextual demands 'as though the performer has all the time in the world.'

Skills are Goal-Directed

All skills are intentional, purposeful, that is, they are goal-directed. This purposeful, deliberate pursuit of a goal that is seen as worthwhile, differentiates skills from other behaviours - such as reflexes and instincts. For example at one level, a deliberate wink is different from an uncontrolled protective blink of the eye-lid. Again we describe movements, such as the flexion, extension and abduction movements of the arm. However, these movements can be integrated into a purposeful pattern of action as in the skilled act of drinking or throwing.

One feature of this goal-direction is that goals may be achieved by a variety of means. That is the motor problem may be solved and the goal achieved by a variety of means. This has been referred to as the problem of motor equivalence. Thus, we can drink from a cup using the right and left hands, with different grisps, or even with the feet, if in the case of thalidomide patients.

Goals and the sub-goal system are an integral part of the knowledge structure system on the one hand and the affective-motivational system on the other. Goal systems are an essential ingredient giving direction, priority and intensity and persistence of effort.

In skilled performance we cannot underestimate the close-links between goals, goal-setting, goal-attainment incentives and motivation.

Skills are Learnt

Alls skills are learnt and indeed the formal acquisition of skill and the teaching, training and coaching procedures are an essential focus in the study of human skills. Behind our investigation into human skills is the motivation that we may be able to enhance and vacilitate the learning process by formal instructional procedures. Although the learning of new skills is obious, there is clearly a close relationship between growth and development and the on-going maturational processes and the learning process, as in crawling, walking, reaching and grasping for example, as evidenced by the orderly sequence of the emergence of these skills. There is strong empirical support for both the 'maturational hypothesis' and 'learning hypothesis', but what is clear for the purposes of the present discussion is that high levels of skilled performance are a consequence of learning and hence systematic and extensive practice.

Skills Develop with Practice

All skills are learnt, refined and eventually mastered through extensive practice. However, it is very clear that the conditions and quality of practice can have very dramatic effects on the rate of learning and the eventual performance. However, as a general principle, performance (and hence learning) seems to proceed according to a power law of practice. What this means is that learning and performances appear to improve in a consistent manner over extensive practice or training periods (thousands of trials and years of practice). In essence, improvement in performance is a linear function of the amount of practice. What is of particular interest is that this power principle of practice is consistent across a wide range of human skills, both in the laboratory and 'real' everyday skills, including a wide variety of athletic and industrial skills.

A number of important implications arise from this power principle of practice. Firstly, it seems that the information processing capability of the brain does not restrict performance, but rather the fall off in performance is associated with loss of interest, motivation and eventually decline in the musculo-skeletal system. Secondly, it highlights the importance of extensive 'effective' practice means. Thirdly, it suggests that if learning is indeed continuous, that indeed the same process is involved and that there are not different learning mechanisms (Anderson, 1985), but rather that information is handled or used differently at different stages in the learning process.

Skills are Permanent

One of the strongest impressions about human skills is that they seem to be permanent '...once you have learnt to ride a bicycle...'. Certainly regularly used skills seem remarkably consistent and stable over long periods of time (years). There is little empirical evidence to show the changes in quality of performance over times as a consequence of little or no use. But it is also clear that skills which haven't been used for sometime can be quickly 'retorted' with practice and use. This feature of permanence suggests storage or memory in a relatively stable form in some longterm storage mode. But it is clear that such storage is in an abstract form in which reconstruction is as important as retrieval.

Skills are Consistent

Witness your signature every time you sign your name. Indeed, it is the remarkable consistency of our writing, and in this case signing our name, that makes unique identification possible. Not only is this writing consistent, there is a remarkable stability and consistency even though the size of the writing may change and different musculature be involved. This consistency of performance over time characterises the whole range of skills from writing, tying shoelaces, to serving in tennis. Such consistency also reflects the level of skill, variability early in practice is replaced by consistency and stability later in practice. Consistency is an important feature of skilled performance both from a practical and theoretical point of view, for it raises important issues about the organisational mechanisms of skill. How can we produce consistent performances time after time, with changing contextual demands. What form of memory system can provide permanence and consistency on one hand, but also be flexible and adaptable on the other?

Skills are Flexible and Adaptable

As we have seen, skills are also flexible and adaptable to changing contextual conditions, indeed this is an essential feature of many athletic skills where surface, weather and other environmental conditions change from one performance to the next. However, an important point to recognize is that adaptability can only be fully effective within a certain 'band width' or range variation. Again, we must ask how can we have consistency and stability on the one hand and flexibility and adaptability on the other. One solution to this problem has been to identify certain stable or invariant features which remain consistent from one context to the next (e.g., relative timing), as well as free variables or parameters which are the specific details (force, velocity, direction) mapped onto the invariant framework to suit or match the changing contextual demands. In addition, there seem to be a number of specialized error-correction or rapid amendment mechanisms which enable a limited range of adjustments to be made during performance (Glencross & Barrett, 1992).

Skills are Idiosyncratic

When we compare the performance of different individuals, it is clearly apparent that there are wide differences in style. Each individual has his or her own idiosyncratic solution — their own characteristic style — ranging from handwriting to serving in tennis. Once again this raises another important principle about human skills, the principle of motor equivalence. That is, the same end result or outcome can be achieved by a number of different solutions or patterns of action. Of course, the motor equivalence principle is demonstrated by our own ability to solve motor problems in a number of different ways — goals can be achieved by different means. Whether we relate the motor equivalence principle to different solutions between individuals or within an individual, we face the same theoretical issues, that is, there can be no direct connection or unique one-to-one correspondence between the goal and the motor solution. However, at high levels of performance, the skilled performer may, or indeed, must use one optimal solution, and only the free parameters can change around this invariant structure.

Skills are Efficient

Skills are efficient in several ways. Efficiency can be considered both in terms of physical and physiological effort and in terms of mental effort.

Physical efficiency relates to the reduction of extraneous muscular action and the effective timing and gradation of agonist, antagonist and synergistic activity. Physiological efficiency relates to the effective use of energy or 'fuel' sources involving the interaction of the aerobic and anaerobic energy systems. Both physical and physiological efficiency are more important in the gross skills of running, swimming and cycling for example. However, their importance in repetitive actitivities such as typing, playing the piano or singing for example, should not be underestimated.

What we are really talking about here are the sets of constraints which define the possible (and impossible) outcomes of skilled action. This has been referred to by Bernstein (1967) as the Degrees of Freedom problem, that is, how does the brain organize and control the very large range of movement possibilities of all the joints (and hence muscles/forces) of the body.

Efficiency can also be understood in terms of the 'mental effort' and the efficient allocation of limited mental resources. Such limitations are evidenced by our inability to attend to several sources of information at the same time. The skilled performer needs to develop efficient and effective cognitive strategies to cope with multiple sources of information and to coordinate multiple outputs. Such limitations can be discussed in terms of the limitations of time (time to process information), limitations of space (the ability to handle competing sources of information) and the limitations of directionality (vision and audition are directional).

Skills are Influenced by Affective Factors

Human skill and performance is markedly influenced by such affective factors as motivation, competition, stress, confidence, etc., which presumably change levels of arousal and/or anxiety and hence the state of the brain which controls the performance. Although the inverted 'U' hypothesis, relating levels of arousal and performance may be seriously challenged, there is no doubt that performance is markedly influenced by changes in level of brain activation. What is not clear is how changes in motivation, competition, stress, etc., influence this level of activation. Further, the difficulty of the task and the personality of the individual all interact to influence the quality of performance.

A major weakness of most learning theories and models about the acquisition of skill (see for example, Anderson, 1987; Mackay, 1987) is that they ignore the affective domain. At the highest level of performance it is these factors, more than any others, which are the preoccupation of the coach and the athlete. Indeed it was this neglect that originally motivated psychologist and sport psychology to become interested in sport and the ideal performance state.

The Functional Nature of Human Skills

The significance of the functional approach to the study of human skills is that it re-directed or re-oriented attention to issues about the functions or control processes involved. This interest in control processes, necessarily implicated the bases for control, that is, information or knowledge. This realisation is at the heart of all cognitive psychology (and cognitive science). This is most recently seen in the interest in cognitive skill and the acquisition of expertise.

Cognitive skills according to Anderson (1982) and Mackay (1987) incorporate all skills from speech, hand-writing, problem-solving in geometry to driving a car and playing tennis. It is argued that all skills are cognitive in nature, involving the processing of information, the focusing of attention on goals and how these might be achieved through problem-solving strategies and how effective solutions may be kept and maintained for future use.

The interest in the study of human skill has clearly shifted to one of a concern for the development of strategies, to the solution of problems within an environment of constraints and of the effective use and development of knowledge and knowledge structures.

We may thus view skill as the development and implementation of cognitive strategies to overcome the limitations of the information-processing system, by the development of sophisticated knowledge structures, which are directed at achieving a specified goal or outcome.

Knowledge and Knowledge Structures

We may regard the expert as having to make two types of decisions:

i. Information telling us which action or actions are appropriate. This is the problem of response selection and involves *Expert Perception.*

ii. Information about how the response needs to be effected; that is, how is it organized to achieve or effect the appropriate action? This involves *Expert Action.*

Let us discuss each of these in turn.

Expert Perception

How does the skilled performer interact with the dynamic environment (e.g., the tennis player, soccer player, driver, chess player)? Expert perception depends not only on the knowledge/information derived from the environment, but more importantly on how this knowledge is organized. It is the knowledge structures (organized into schema) which largely determine what information we pick up. The light hitting the eye is the same for the master and child - but only the master is equipped to 'pick-up' that which is relevant (Neisser, 1976).

The studies of de Groot (1965) and Chase and Simon (1973) suggest that expert perception of elite players is a learnt knowledge structure involving the chunking together of chess pattern positions (real game situations) organized as collectives of chunks. The experts ability depends directly on how many chunks are used to encode a position. It is estimated that the number of chunks available is about 50.000. This is acquired by an immense amount of time and effort spent specifically at the game, viz., practice must be very specific.

Why so many chess chunks (50.000)? It is because of the number of combinations of chess pieces, number of squares and the rules of movement of each piece. Chess chunks are organized hierarchically — higher-level chunks encode large sub-patterns of pieces — thus rapid perception can be achieved by scanning only the higher order chunks. However, the actual configuration to which they apply do not show up often and so to gain coverage of all chess positions (viz., environmental or display exhaustion), requires an immense number of high-level chunks. This is a more sophisticated level of knowledge organization (structure) than cue or feature detection.

The acquisition and organization of these perceptual chunks, from many individual 'unorganized' single features, to fewer medium-sized chunks, to eventually still fewer larger, hierarchically organized chunks, is what we mean by learning and accords to a Power Law of Practice.

Is this what happens in dynamic sporting/driving/flying environments, but with both spatial and temporal characteristics integrated with informational features? Can we determine the number of tennis/soccer chunks for example? How are these chunks acquired — must there be perception-action-integration — does action facilitate perceptual chunking? Can perceptual chunking be achieved in isolation (by film/video displays)? Can it be facilitated by understanding the knowledge structures? Is this the basis of mental practice? Increased chunking also represents increased automaticity:

> The interesting thing about them (simple automatic learning mechanisms) is that expertise comes about through the use of knowledge and not by the analysis of knowledge. There is no intelligent homunculus deciding whether incoming knowledge should be stored declaratively or procedurally or how it should be made more efficient (Anderson, 1981, p. 83).

Expert Action

The second (or parallel) phase is that a response has to be made on the basis of the perceptual analysis described earlier. Do the same principles about chunking apply to the information (knowledge) used to guide and build the pattern of action? Unlike some forms of learning, the structure of the response is critical to success, as with typing, playing the piano and serving in tennis. Many psychologists and theories (e.g., Anderson) often ignore response quality — it is assumed that the animal acts appropriately.

What do we mean by expert action? The characteristics of the action pattern of the skilled performer (which I discussed earlier) include:

(i) a high level of serial, spatial and temporal organization.

(ii) the action pattern is remarkably consistent and stable.

(iii) the action pattern, however, is idiosyncratic. Yet in spite of this individuality there must be certain basic invariants which must occur in all subjects.

(iv) the action pattern is adaptable and flexible to changing contexts and conditions. This usually involves changes in assigned parameter values.

(v) the action patterns are efficient, in that they are achieved by the most effective organization of the muscular activity, and the minimum of extraneous effort. At the same time such skills are efficient in terms of the mental effort and the allocation of limited resources.

Collectively, effector organization involves the following processes (Glencross, 1978): effector discrimination (the selection of the appropriate response units), sequencing (ordering the response units into the correct sequence), phasing (the internal timing of the ordered sequence), gradation (the allocation of the appropriate force by each response unit) and timing (the coincident timing of the whole sequence to an external event or object).

How is this achieved? These actions also accord to a Power Law of Practice. Does this reflect the chunking of information upon which the movement is based? The ultimate chunking is represented by the organization of knowledge into a motor program. What is the form of knowledge upon which movement is based, it need not be verbal and symbolic, and clearly vision and proprioception information are involved. However, we know little about the knowledge structures upon which movements are based.

The Motor Learning Issue - Knowledge about Movements

Is motor learning unique or is it a special case of skill learning? On the other hand, is it the same as all learning, and accords to the principles of skill learning? What do we mean by motor learning? We mean that a pattern of actions must be controlled to achieve a specified outcome. Initially this involves information of two types:

i. Information telling us which action/actions are appropriate (the problem of response selection), to achieve an outcome or goal; and then

ii. Information about what pattern of effectors to organize (effector organization), that is how to organize and effect the appropriate action.

I propose that often motor learning researchers have been preoccupied with the latter issue (effector organization) and ignored the former issue of response selection. We do not learn to make movements — there is no motor learning as such, rather we learn to use the information or knowledge about which the movement is based — we learn the knowledge structure of a new movement or movement/action pattern. Does this mean we need to understand more about the information and knowledge upon which movements are based? Do we use symbolic information for movements? Do we use declarative and procedural knowledge about movement? What of implicit and tacit knowledge? Did we need explicit information at some developmental stage — as an infant or child? Of course visual information could replace verbal description (declarative/procedural knowledge) in some instances. Motor learning has failed to recognize these problems.

Knowledge and Imagery

Finally, le me discuss another recent initiative. Anderson (1990) has categorized knowledge as declarative (knowledge about facts, objects, events) and as procedural (knowledge about sequences or procedures). Paralleling such knowledge and knowledge structures is knowledge in the form of images. The link between explicit and implicit knowledge and images and imagery, would seem to be crucial to our understanding of learning and performance, particularly of human skills.

One of the difficulties in investigating the knowledge structures in expert systems is that we do not always have conscious access to the knowledge upon which performance is based. Much of the organization of the knowledge upon which action is based is outside or beyond consciousness. This is because thought contents in themselves lack the sensory quality necessary for an object of conscious experience (Horne, 1991).

We may consider imagery as percept-like experience of thought contents. It is also suggested that vividness of experienced imagery is related to the information or knowledge quality of corresponding representations. Vivid images retain more of the detail of external events. It has been proposed that imagery represents the underlying cognitive operations (which correspond to patterns of neural activity (Horne, 1991).

Horne (1991) proposes that imagery involves not only the centrally driven composition of a representation which is percept-like in its structure, but also the central induction of corresponding sensory processing, that is, the perceptual structuring that would have been involved in forming such a representation during direct perception. What follows on from this is the notion of reverberation or persistence, that is, persisting sensory activity is necessary to provide the 'sensory' pheomenon of a conscious percept produced by that activity. It is suggested that this is an integral part of controlled information processing (which may be lost or reduced during automatic processing).

Human skill and the skilled action is a consequence of the schematic representation and organization of knowledge, increasing in fine detail until it is manifest as an over action. Such reverberatory activity provides the basis for a comparison or 'cross-check' of the computational solution for action. It is possible that imagery is implicated in this 'checking' operation. Central to this checking procedure is that the input to a mental operation (computational knowledge structure) persists for a time that is longer than that needed for the operation or action to occur.

Horne (1991) elaborated this idea further:

> ...perceptual processing must be automatically checked during the elaboration of action, with the results of the checking procedure determining the amount and timing of any necessary resourcing of the perceptual component and subsequent elaborative steps... It follows that sensory information corresponding to a particular percept must survive for a short time after it has been input to down-stream processes structuring the percept. We therefore require the existence of short-term sensory registers so that the results of inchoate perceptual structuring may survive for long enough to play a role in the resourcing and verification of the higher order analyses to which they give rise. (p. 40)

In summary the functions of such imagery include:

i. Imagery provides a verification or check on the up-coming computation for action.

ii. Imagery is involved in the allocation of attentional resources during the elaboration action. It may thus facilitate concentration.

iii. Imagery may also facilitate cognitive processing, for example there is evidence that imagery aids in the reconstruction of past action.

iv. Finally, it is interesting to speculate that the imagery and efference copy/corollary discharge are related and serve similar functions in the control of actions.

These new directions in the study of human skill, in particular the elaboration of knowledge and knowledge structures and the understanding of the nature and role of imagery, offer exciting new possibilities in the acquisition and performance of human skills.

Conclusions and Implications

In this paper I have tried to take a forward-looking view of where research into human skill is heading. In particular, I have referred to developments in the broader field of cogntive psychology and the recent research in cognitive skills. Sport psychologists, at both the practical and theoretical levels, need to be involved in the study and understanding of human skill (Glencross, Whiting & Abernethy, 1994).

The recent developments in cognitive skill have highlighted the understanding of knowledge and knowledge structures. I believe that this new research thrust is an important and exciting development, which should be of benefit at the theoretical and practical levels. Questions related to declarative and procedural knowledge will no doubt have implications for how we teach and coach skills. The study of the development of skills in young children may throw light upon how knowledge is used prior to the development of large scale automaticities. Again, once skills have been acquired, how can changes in technique or style be achieved, from an understanding of the knowledge and knowledge structures involved. What knowledge do the master coaches use to achieve such subtle changes in elite athletes? Researchers would do well to listen to and observe the 'language' of the athlete and the coach in achieving performance change and improvement.

One of the most exciting possibilities is in the area of imagery, as a form of knowledge. How does imagery relate to the more conventional issues of mental practice, mental rehearsal and visualization, for example, which are of central interest to sport psychologists? I believe the knowledge architecture approach now provides a meaningfull framework within which to address these issues more coherently and systematically.

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Is Conscious Awareness of Environmental Information Necessary for Skill Learning?

Richard A. Magill, USA

Learning a complex motor skill requires a person to learn to coordinate limb and body movements according to the demands and characteristics of the environment. From a learning perspective, this means that something about these characteristics and what they mean in movement terms must be learned. In fact, the acquisition of this environmental information is a central part of the often overlooked model of learning proposed by Gentile 20 years ago (Gentile, 1972). She argued that during the initial stage of learning, the learner must acquire knowledge about the relevant stimuli that are responsible for the movement that must be performed.

An example of a sport skill learning situation will help illustrate this point. To successfully return a serve in tennis, a person must be able to select the critical information that will influence the plan and execution of the return. There are many sources of information available and there is much information in those sources. For example, the player could observe the ball, the racquet, the server's arm, the server's head, or body, or some combination of these. Each of these sources contains information that may or may not be relevant for planning and executing the return of serve.

The question that I will address in this paper concerns the learning of this critical environmental information that is vital to successful skill performance.

The specific question I will address is, does the learner need to be consciously aware of the critical environmental information during practice or can this information be learned without being consciously aware of it? An important point to note here is that you should think of the term "conscious awareness" in terms of whether the person can verbally describe the environmental information to another person. The answer I propose to this question is that the learner does not have to be consciously aware of critical environmental cues in order to learn to successfully perform a skill that is dependent on the use of that information.

I will do two things in the remainder of this presentation to address this conscious awareness issue. First, I will describe some research evidence from my laboratory that provides empirical evidence to support the negative answer to the question. Second, I will describe some implications this negative answer has for motor learning theory as well as for developing effective instruction and practice strategies to facilitate the learning of critical environmental information.

Research Evidence for Learning Without Conscious Awareness

When questions arise concerning the learning or use of critical environmental information necessary for performing a motor skill, the role of the visual system must be considered. This is because the visual system is the perceptual system responsible for detecting and using this information. Although Gentile (1972) implied in the discussion of her learning model that awareness of environmental stimuli is important during the early learning stage, there is an alternate view that argues that awareness of this information is not necessary. The basis for this alternate view is David Lee's notion of how the visual system works in the detection and use of visual information to guide coordinated movement. He argues that this information is detected and used in an automatic, non-conscious manner (e.g., Lee, 1980). Unfortunately, the empirical evidence testing Lee's view has been based primarily on the performance of well-learned skills, such as long jumping (Lee, Lishman & Thomson, 1984), jumping from different heights (Sidaway, McNitt-Gray, & Davis, 1989) and running over irregular terrain (Warren, Young & Lee, 1986). There is very little evidence on which to base an argument concerning the acquisition of a new skill. The two experiments I will describe address the use of vision to detect regularity in the environment while learning a skill.

The experiments are based on one reported by Richard Pew (1974) in which subjects learned a complex 60-sec. tracking skill. The tracking task involved moving a control handle to move a cursor to follow the movement of a cursor on an oscilloscope. The pathway of the target cursor was random on each trial for the first and third 20-sec. segments of the 60-sec. pathway and the same on each trial for the middle 20-sec. segment. Subjects were not told about this tracking pathway characteristic in advance. After 11 days of practice during which there were 264 trials, subjects were performing the repeated segment more accurately than the other two segments. However, not one of the subjects reported awareness of the repeated regularity of the middle segment. Here then was evidence that learning to coordinate and control limb movements according to the characteristics of environmental constraints could occur without conscious awareness of the regularity contained in the environmental information.

We have conducted two experiments that were designed to replicate and extend the Pew experiment (Magill & Hall, 1989; Magill, Schoenfelder-Zohdi & Hall, 1990). The tracking patterns we developed were presented on the monitor of a microcomputer. To control for pattern characteristics, we developed over 100 patterns so that specific patterns could be presented on each trial. Examples of two of these patterns can be seen in Figure 1. In the first experiment, we followed the procedure used by Pew where the middle 20-sec. segment was a pattern that was repeated on each trial while the first and third segments were random on each trial. In the second experiment, we changed the repeated segment to the first 20-sec.

segment. We reasoned that perhaps subjects were unaware of the repeated middle segment because it was embedded between the two random segments. So, we thought that moving the repeated segment to the first 20-sec. would increase the probability of subjects' being aware of this characteristic. The two examples of patterns in Figure 1 were from this second experiment.

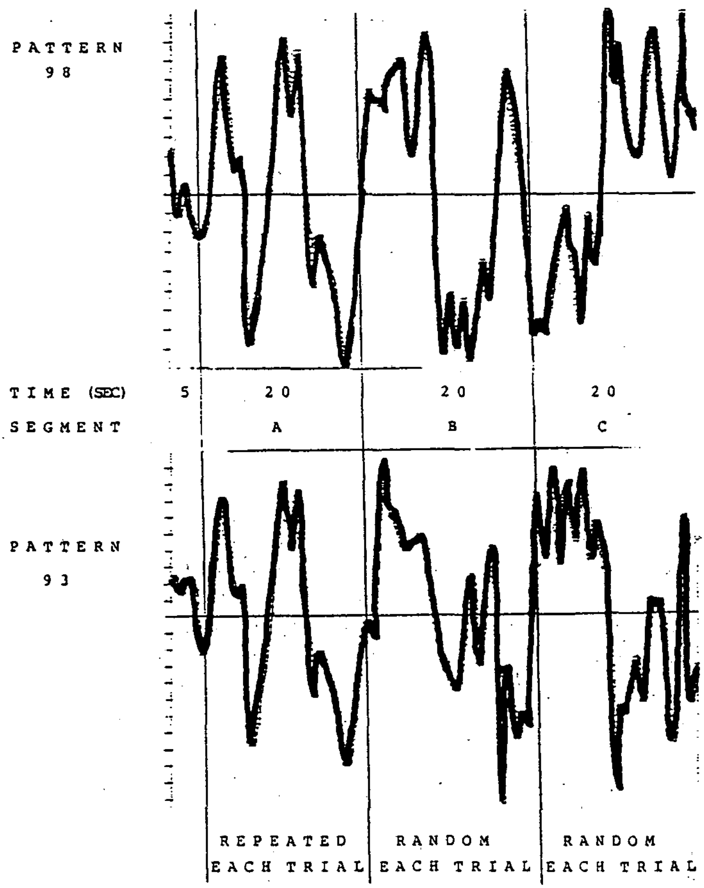

Figure 1. Two examples of criterion tracking patterns.

From the subject's perspective, the only visual information was in the form of two small crosses on the computer monitor, which is diagrammed in Figure 2. The blue cursor served as the target cursor while the red cursor was the subject's cursor. Subjects controlled the movement of their cursor by moving a 43 x 13 cm lever located on a table top in front of the monitor and which moved along the horizontal plane of the table top. The lever was pivoted at the elbow end by the axle in a near-frictionless ball bearing and enabled the lever to be moved easily in the left and right directions. Moving the lever to the right, that is, away from the body, moved the cursor up the Y-axis of the monitor screen, while moving the lever to the left, that is, toward the body, moved the cursor down the Y-axis. A potentiometer was attached to the axle of the lever to allow analog recording of lever movement.

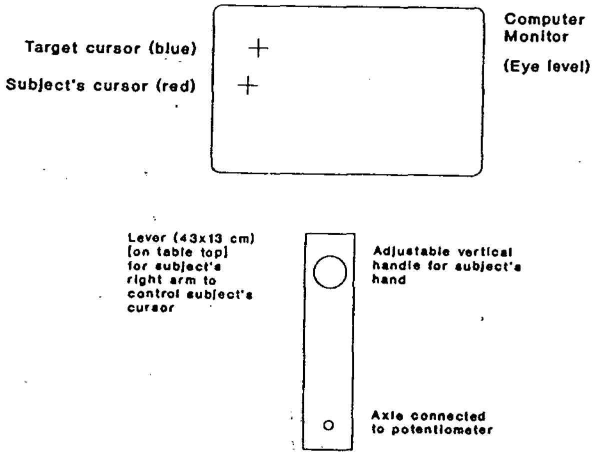

Figure 2. Visual information from subject' perspective.

Both experiments followed the practice and testing protocol described by Pew (1974). This protocol is presented on Table 1 according to what was done and the number of trials each day, except for days 6, 11, 12, and 16, when they performed 10 trials like those on the other days and then 10 trials with a concurrent verbal memory task. Additionally, two characteristics of the repeated segments were altered. On day 11, 8 trials were performed where the repeated segment was inverted, where the cursor moved in the opposite direction from previous trials. And, on day 16, 10 trials were performed where the repeated segment was a random pattern. An important part of the experiment occurred at the end of practice on day 11. The subjects were interviewed by systematically asking them questions about their awareness of the repeated characteristic of the repeated segment.

Table 1. Testing protocol for subjects.

Days	No. of trials	Trial characteristics
1-5	24 each day	Regular
6	10 10	Regular W/current memory task
7-10	24 each day	Regular
11	10 10 8 *	Regular W/current memory task Segment A inverted Interview
12	10 10	Regular W/current memory task
13-15	24 each day	Regular
16	10 10	W/current memory task Segment A random
	Total = 376 Trials	

The results of both experiments were consistent in supporting those reported by Pew. In Figure 3, you can see the performance results for the three segments of the trackings task for Experiment 2 where the first 20-sec. segment (Segment A) was repeated. As you can see, subjects improved their performance for all three segments of the task, thereby showing improvement in their tracking skill as a function of practice. More importantly, performance on the repeated segment A was superior to the performance on the random segments B and C. These results are the same as those found in Experiment 1, where the middle 20-sec. segment (Segment B) was repeated. Also, in both experiments, the results of the interview at the end of practice on day 11 indicated that not one of the 12 subjects in these experiments was aware that one of the segments was repeated on every practice trial.

One final point about the results of these experiments needs to be made. In both experiments, there was evidence that learning the repeated segment occurred despite the lack of conscious awareness of its characteristics. This evidence was based on performance characteristics of the repeated segment for the two transfer conditions used in both experiments. When the repeated segment was presented as a random pattern on each of 10 trials on day 16, subjects in both experiments performed all three segments similiarly. These results suggest that subjects learned something specific relative to the characteristics of the repeated segment rather than a general tracking capability. Also, when the repeated pattern was inverted on each of 8 trials on day 16, subjects performed this segment better than the other segments. These results indicate that what was learned about the repeated segment was capable of being generalized to a novel variation of the pattern that was learned.

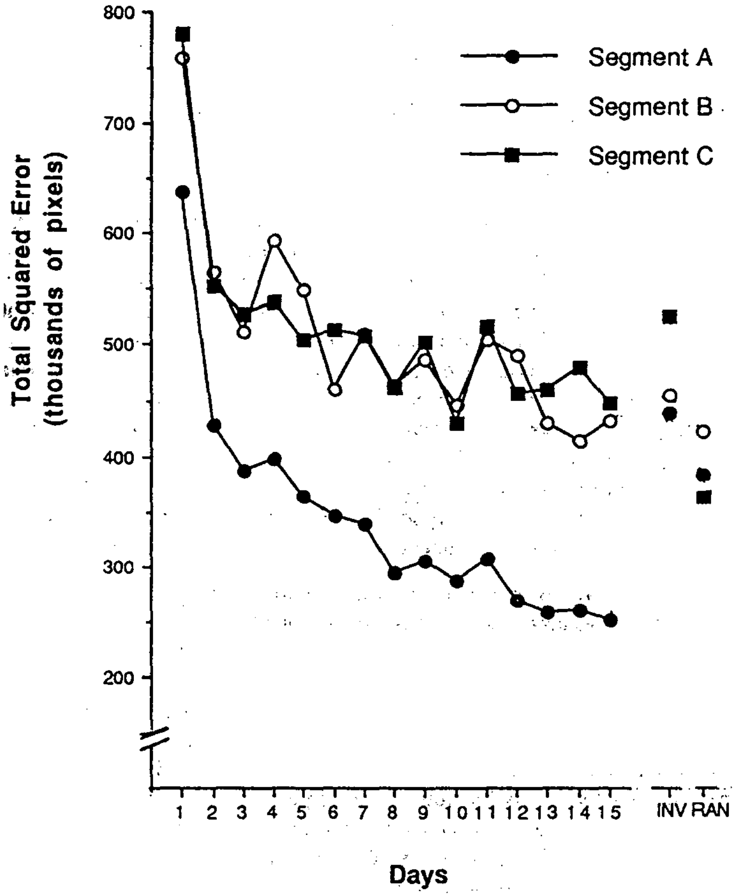

Figure 3. Total squared errors (thousands of pixels).

Implications for Motor Skill Learning Theory

The results of these experiments provide evidence then that the visual system can detect and use regularity information in the environment in a manner that does not require the person to be consciously aware of that information. This invariant information is used to systematically constrain the limb during practice so that the movements are produced according to that regularity. If we consider these results and this conclusion in relation to the theory of motor learning proposed by Gentile (1972) that we described earlier, then there is clear support for her view that in the early stage of learning the learner detects relevant stimuli to control limb movement. However, contrary to what she implied concerning the need for the learner to be aware of this information, the present results argue that such awareness is not needed.

This issue of awareness of environmental invariant information that regulates skill learning and performance is one that has had little attention over the years. In fact, two of the more popular theories of motor learning, the closed-loop theory of Adams (1971) and the schema theory of Schmidt (1975), say nothing about the perception of information in the environment that regulates movement. These theories operate on the assumption that information is taken into the information processing system and operated on in specific ways. The focus of these theories is on what are the operations that produce coordinated movement. In fact, only the learning model by Gentile (1972) has addressed the question of selecting relevant environmental information during the skill learning process. In terms of motor learning theory, then, we can argue that any theory of skill acquisition must accommodate the results of experiments such as the two I have described here.

One final point needs to be made concerning motor learning theory. While active debate continues concerning whether perception of this environmental information is direct or indirect, the notion of conscious awareness of that information has been largely ignored. This point is important to emphasize as neither direct nor indirect perception views predict awareness characteristics, although the direct perception viewpoint implicitly supports the point that visual perception occurs without conscious awareness. However, it is possible to make a case in support of either awareness or non-awareness for both views of perception. Since a theory of skill learning must incorporate the perception-action relationship, it is essential that the question of awareness of environmental information regulating movement be addressed in describing this relationship.

Implications for Motor Skill Instruction

The view that conscious awareness of environmental information is not necessary for skill learning has implications for instruction as well as for motor learning theory. Perhaps the most significant implication concerns the role of the instructor in his or her interaction with the student. If conscious awareness of environmental information is essential for skill learning, then the instructor must take an active role in directing the student's attention to the relevant cues in the environment. This is one of the recommendations made by Gentile (1972) when she discussed the application of her learning model to teaching motor skills. However, if conscious awareness of environmental information is not essential for skill learning, then there is little need for the instructor to perform this type of attention directing role.

What becomes more critical for the instructor now concerns the environmental conditions in which the skill is performed during practice. It becomes important that the teacher creates a practice environment in which the student will experience information rich environments that will allow the student's visual system to detect the information invariants as he or she practices the skill. The key feature of an information rich environment is that the regulatory stimuli, which are the information invariants, will be seen as many times as possible and in a variety of situations. As the student increases the amount of experience in these environments, the visual system becomes increasingly attuned to the informational invariants involved in coordinating and controlling the limbs. This attunement becomes incorporated into the processes of learning to achieve the goal of the skill being practiced.

In terms of directing students' visual attention, the results of our experiments indicate that the teacher does not need to direct the student's attention to specific characteristics of the opponent, racquet, or ball, to continue using the tennis serve return situation. This means that it does not seem to be necessary to tell a student to "pay attention to the spin of the ball" or to "pay attention to the angle of the racquet face". These types of directions are too specific and are not needed. What would appear to be needed in terms of directing students' visual intention in these types of situations can be established from some recent work produced by Bruce Abernethy in Australia (e.g. Abernethy & Russell, 1987). Expert athletes in racquet sports direct their visual attention to specific regions of the opponent's action. For a tennis serve, for example, the expert directs visual attention to the server's racquet and arm. This suggests that the most the teacher would need to do is to direct attention to a certain region of the opponent's action. Rather than trying to make the student look for what the arm is doing or how the racquet is moving or how the ball is rotating, the teacher can specify attending to the racquet and ball region and then let automatic visual processes detect the informational invariants. What is important for the student then, is that he or she practice as many returns of serve as possible with attention directed to the important region containing the regulatory information needed to direct the return of serve action.

One final point is worth noting. Two other characteristics of the experiments I just described also have implications for instruction. In both of our experiments, subjects showed systematic improvement in their tracking performance. And, subjects were given knowledge of results after every trial in terms of a performance score. Subjects indicated that this performance score information was very important for them as they practiced. These two characteristics suggest that two practice conditions characteristics are important in learning environments related to those described here. One characteristic is that there should be opportunity for students to improve their performance as they practice. The other is that there needs to be a means for students being informed that this improvement is occurring. The most obvious way to establish these two conditions is to provide some form of augmented feedback about success to the student during practice. It is likely that this feedback performs a motivational rôle in the learning process in this situation since the augmented feedback provides information about his or her progress toward achieving the goal of the skill being practiced.

Conclusion

In conclusion, it seems that people interested in motor skill learning and instruction have been led to believe that conscious awareness of critical elements in one's environment and about one's movement are essential parts of the learning process. Experiments such as the two I reported here as well as others that are beginning to appear in the research literature provide evidence that such a view has been overly influential. Skill learning can occur without conscious awareness of environmental characteristics that regulate movement. However, we need to know more about conditions in which awareness does and does not play a role and what type of effect awareness has on learning and performance. Based on current evidence, however, further study of the role of conscious and unconscious awareness has the potential to have a significant impact on current views of skill learning and instruction.

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NEUE ZUGÄNGE ZU EINEM ALTEN PROBLEM: DIE AUTOMATISATION

RILO PÖHLMANN, RITA NOLLMEYER UND ANTJE WOLF, DEUTSCHLAND

Nachdem in den zurückliegenden Jahren die Problematik des motorischen Lernens im Mittelpunkt der wissenschaftlichen Arbeit gestanden hatte, wurde in Zusammenarbeit mit den Kooperationspartnern der Medizinischen Fakultät in Jena das interdisziplinäre Projekt "Handlungs- und Bewegungsautomatisation" vorbereitet.

Den Vorkenntnissen und Vorleistungen aller Beteiligter gestundet, aber auch der Problemgeschichte Rechnung tragend, wurden in konzeptioneller Hinsicht folgende Schwerpunktsetzungen vorgenommen:

- Automatisation — Wege und Irrwege zu ihrer Erfassung im Rahmen der Natur-Kultur-Kontroverse und dargestellt am Beispiel Bewußtes-Unbewußtes bei der Bewegungsregulation.
- Automatisation — Drillpatterns und dynamische Stereotype als Formen reflextheoretisch interpretierter Aktivität und als Funktion der Anzahl von Übungswiederholungen.
- Automatisation — Fertigkeiten, Automatisation und Action slips aus der Sicht der kulturhistorischen Handlungstheorie.
- Automatisation — Kontrolle und Aufmerksamkeit als informationstheoretisch-kognitionspsychologische Zugänge.
- Automatisation — zentrale Programme, periphere Parametrisierung und der Fakt der Nichteindeutigkeit in der Synergie von Zentrum und Peripherie.

Der letztgenannte Schwerpunkt mußte aus methodentechnischen Gründen in drei Etappen realisiert werden. Die erste bestand aus Untersuchungen der zentralnervalen Vorgänge mittels EEG-Analysen. Die zweite stellte die peripheren Veränderungen in den Mittelpunkt. Als Methode kam u.a. das EMG-Mapping zum Einsatz. Über die ersten Ergebnisse wird hier berichtet. Die dritte Etappe sollte die Wechselbeziehungen zwischen Zentrum und Peripherie und die Spezifik des Prinzips der funktionellen Nichteindeutigkeit nach N.A. Bernstein abklären.

Pilotstudie: Periphere Aspekte der Automatisation

In Zusammenarbeit mit dem Institut für pathologische Physiologie wurden als Zugang zunächst periphere Anteile von Automatisationsprozessen ausgewählt.

Zielstellung

Das Anliegen bestand in der Schaffung muskelphysiologisch-peripherer Ausgangsdaten in Verbindung mit motorischen Leistungskennwerten für einen späteren Zentrum-Peripherie-Vergleich. Gleichzeitig galt es im Rahmen einer bestimmten Aufgabenklasse, Erfahrungen mit dem EMG-Mapping als Methode, also einem bildgebenden Verfahren zu sammeln.

Aufgabe

Als Repräsentant einer bestimmten Aufgabenklasse wurde eine werkzeuggebundene, feinmotorische Manipulationshandlung der oberen Extremitäten in Form einer Strickaufgabe gewählt. Im Rahmen einer 3-Punkte-Messung waren als Testprobe jeweils 50 rechte sowie 50 linke Maschen mit und ohne Blickkontakt zu realisieren.

Methodik/Population

Das methodische Vorgehen folgte in etwa dem Novizen-Experten-Paradigma. Untersucht wurden dreimal zwei Extremgruppen. Die eine bestand aus hochgeübten und versierten Probanden (Expertengruppe E), die andere aus absoluten Anfängern (Novizengruppe N). Die Novizengruppe absolvierte ein kontrolliertes Ausbildungstraining von 10 Trainingseinheiten à 60 Minuten mit fixiertem Frequenzregime. Bei den Novizen handelte es sich um 10 männliche Anfänger, bei den Experten um 4 versierte weibliche Strickerinnen.

Analysedaten

Erfaßt im Leistungsbereich des motorischen Outputs wurden die Strickgeschwindigkeit sowie die Strickfehler. Die EMG-Daten wurden abgeleitet mittels 16 Elektroden von jeweils Unterarm, Oberarm sowie Schulter. Die Ableitungen erfolgten von der rechten Körperseite. Alle Versuchspersonen waren Rechtshänder. Die Anbringung der Elektroden erfolgte standardisiert und im quadratischen Abstand.

Auswertemodus

Es erfolgte eine polygrafische Registrierung der jeweils 16 monopolaren Oberflächenelektromyogramme. Die Quantifizierung geschah mittels Leistungsspektralanalyse (FFT). Dann wurden die statistisch repräsentativen Spektralparameter extrahiert sowie eine lineare Interpolation der nicht mit Elektroden besetzten Bildpunkte durchgeführt. Die entsprechenden Farbmaps ergaben sich aus der visualisierten Wertematrix.

Die Bildauswertung wurde am PC mittels einer Software der Firma "Noraxon" (Finnland) realisiert. Als Kriterien fungierten zunächst

- die Größe der Maximalwerte der spektralen Leistung
- die Lokalisation der maximalen myoelektrischen Aktivitäten
- die Zeitdauer des Auf- und Abbaus der maximalen Leistungswerte.

Methodenkritik

Die Ableitungen der 16 Elektroden von Unterarm, Oberarm und Schulter erfolgten sukzessiv und nicht zeitsynchron.

Im Rahmen der Pilotstudie war es nicht möglich, männlich/weiblich gemischte Probandengruppen sowohl im Novizen- wie Expertenbereich zusammenzustellen.

Der Meßpunktbeginn erfolgt noch handgetriggert und die Auswertekriterien wurden über die Bildgebung ermittelt.

Eine kinemetrisch synchrone Erfassung der Bewegungsabläufe erscheint notwendig, da mit zunehmendem Expertenniveau auch die Arten der individuellen Lösungstechniken ansteigen.

Ergebnisse/Schlußfolgerungen

1) Die Handlungsfehler verringerten sich erwartungsgemäß von durchschnittlich 5 Fehlern pro 50 Maschen zu einem Fehler pro 200 Maschen. Im Verlaufe des Stricktrainings kommt es zu einer hochsignifikanten Erhöhung der Strickgeschwindigkeit. Trotzdem sind die Strickzeiten der Experten noch um etwa das Dreifache (60s : 175s) geringer als die der Novizen nach Abschluß des Trainings. Auch die wieder auftretende Verschlechterung bei Stricken mit unterschiedlicher Wollstärke deutet auf den geringen erreichten Automatisierungsgrad hin.

2) Insgesamt konnte festgestellt werden, daß bei den Experten ein auf einen enge-

ren Bereich begrenzter Einsatz der Muskelaktivitäten erfolgt. Tendenziell ist die Einengung der räumlichen Aktivitätsverteilung auch bei den Novizen im Vergleich vom 1. zum 3. Testdurchgang nach Training nachweisbar.

3) Das charakteristische Zeitmuster war lediglich über den Auf- und Abbau der Maximalwerte der spektralen EMG-Leistung zugänglich. Dabei kam es zu typischen Veränderungen, aber sowohl in Richtung Verlängerung als auch Verkürzung. Das Typische bestand in einer Zunahme der Art und Weise des Auf- bzw. Abbaus sowie einer Tendenz zur oszillierenden Gleichmäßigkeit.

4) Die Hypothese, daß sich im Verlaufe des Lernprozesses die Muskelaktivitäten verringern, konnte unter den Bedingungen unserer Pilotstudie nicht bestätigt werden. Inter- und auch intraindividuelle Unterschiede in den Lösungsstrategien, verbunden mit verändertem Anspruchs- bzw. Leistungsmotivationsniveau sind hier zu beachten.

5) Es ist abschließend nochmals auf den Charakter und die Unzulänglichkeiten der Pilotstudie hinzuweisen. Dies gilt für die geschlechtergemischte relativ geringe Anzahl der Versuchspersonen, die Verbindung von EMG mit ausschließlich Endproduktdaten der motorischen Leistung, die offensichtlich noch immer zu geringe Trainingsphase sowie den Umstand, daß mit steigendem Aneignungsniveau zunächst mit intraindividuellem Wechsel der Lösungsstrategien zu rechnen ist. In der Automatisationsphase sind dann interindividuell unterschiedliche Lösungsstrategien auch anhand der EMG-Mappings zu erwarten.

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3

Interne Repräsentation
Internal Representation

DIE REPRÄSENTATION EINER INTENTIONALEN BEWEGUNG

VLADIMIR GIKALOV, SCHWEIZ

Die Repräsentation des Wissens als Erfahrungsspeicherung wird vor allem in den lerntheoretischen Modellen ausführlich diskutiert, denn die Resultate des Lernens sind das Wissen, und die Strukturen, die das Wissen aufbewahren, sind die Repräsentationen.

Die theoretischen Ansätze unterscheiden sich vielfach in den Vorstellungen, unter welchen Bedingungen der Lernprozeß optimal abläuft. Die Annahme aber, die Wiederholung sei eine wichtige Voraussetzung für den Lernfortschritt, wurde ausnahmslos von allen theoretischen Positionen postuliert. Das bedeutet, daß der Lernende die wichtigen Aspekte der Lernsituation wiedererkennen muß. Das funktionale Wiedererkennen setzt voraus, daß gewisse - nicht alle - Merkmale und/oder Merkmalskombinationen der Situation als "bekannt" erscheinen, d.h., sie müssen repräsentiert sein, wenn sie als Referenz für die Unterscheidung dienen, ob etwas als "bekannt" erscheint oder nicht.

Die Repräsentation einer intentionalen Bewegung wird je nach theoretischer Position unterschiedlich dargestellt (Abbildung 1):

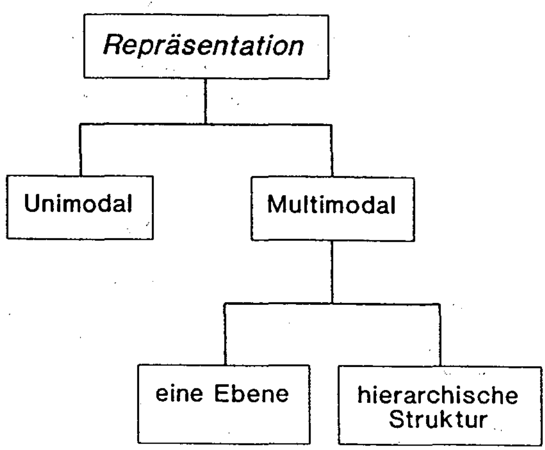

Abbildung 1. Darstellung der Modelle der Repräsentation.

Unimodale Repräsentation

Bernstein (1984) postuliert ein Modell der unimodalen Repräsentation einer intentionalen Bewegung in einer abstrakten Form, die mit der Muskelaktivität nichts zu tun hat. Nach dieser Darstellung sind im zentralen Nervensystem (ZNS) motorische Schemata (auch Engramme genannt) vorhanden, welche in einer Art Spuren den ganzen Bewegungsablauf repräsentieren. Die Engramme besitzen bestimmte Aspekte des phänomenalen Bewegungsablaufes. Die Grundlage bilden die räumlich-zeitlichen Dimensionen der Bewegung. Dabei lassen sich verschiedene untergeordnete Merkmale unterscheiden (Distanz, Winkel, Geschwindigkeit usw.). Die Feststellung, daß bei der wiederholten Bewegungsausführung eine große Homogenität besteht, unterstützt diesen Ansatz.

In dem Modell wird postuliert, daß ein Engramm nicht alle Einzelheiten des Bewegungsablaufes enthalten muß. Eine Generalisierung wird durch die Verfügbarkeit von mehreren Bewegungsvarianten erklärt. Außerdem lassen sich unterschiedlich übergeordnete Zusammenhänge der Handlungssequenzen erkennen. Die Information soll in einer Form gespeichert werden, daß sie für die jeweilige Aufgabe verfügbar ist. "Engramm", "motor image" und "Bewegungsgestalt" werden in diesem Modell als Synonyme verwendet.

Andere Autoren dagegen sind der Meinung, daß die Optimierung der Bewegungsreproduktion nur durch die Interaktion von mehreren Kodierungsmodi erreicht werden kann (vgl. Anderson & Bower; 1973, S. 432). Von dieser Position aus stellt sich das Problem der operationalen Interaktionen von Repräsentationen. Eine unimodale Repräsentation von intentionalen Bewegungen ist schon unter Berücksichtigung der Komplexität menschlicher Informationsverarbeitung sehr unwahrscheinlich (vgl. Engelkamp & Denis, 1990, S. 222).

Multimodale Repräsentation auf einer Ebene

Die Dual-Kode-Theorie (Paivio, 1971) unterscheidet das verbale und das imaginale Kodierungssystem, welche zwar unabhängig sind, aber komplementär arbeiten. Das imaginale System repräsentiert alle Informationen mit Ausnahme der verbalbegrifflichen. Das bedeutet, daß eine Vorstellung keineswegs nur auf die bildhafte Form reduziert wird. Eine Vorstellung kann ein Abbild von verschiedenen Wahrnehmungsmodi und ihrer Kombinationen sein. Das imaginale System verarbeitet bevorzugt die konkreten Objekte oder Ereignisse. Die Informationseinheiten werden in räumlichen Strukturen organisiert. Abstrakte Inhalte werden im verbalen System repräsentiert. Die Dual-Kode-Theorie postuliert vier Stadien der Informationsverarbeitung. Im ersten Stadium erfolgt lediglich die Informationsaufnahme. Weitere Phasen sind dadurch gekennzeichnet, daß die Information hinsichtlich ihrer Bedeutung analysiert wird. In der zweiten Phase werden die nonverbalen Stimuli imaginal kodiert und in der nachfolgenden, der referenziellen Phase, bilden sich Verbindungen zwischen den Repräsentationen. Die Vorstellungsbilder werden verbal "etikettiert". Damit wird die Bedeutung der Inhalte zumindest teilweise geändert und es werden neue Zusammenhänge gebildet.

Auf der letzten Verarbeitungsstufe entstehen die assoziativen Ketten. Mehrere imaginale und/oder verbale Repräsentationen werden hier zusammengefügt. Die Dual-Kode-Theorie von Paivio (1971) postuliert zwar, daß jede Repräsentationsform auf einen bestimmten Situationstyp zugeschnitten werden kann, aber es wird keine Hierarchie zwischen den Repräsentationen gefordert (vgl. Engelkamp & Denis, 1990, S. 223). Der Ablauf einer motorischen Fertigkeit wird voraussichtlich auf mehreren Ebenen kontrolliert und gesteuert. Die hierarchische Struktur der Kontrollebenen läßt sich schon aus den Erkenntnissen über die neurophysiologischen Funktionen des ZNS ableiten (vgl. z.B. Heuer, 1985). Auf den Ebenen der Repräsentationen werden unterschiedliche Operationen postuliert, die den Merkmalen der jeweiligen Ebene entsprechen.

Hierarchische Struktur der Repräsentation

Eine hierarchische Struktur der Repräsentation wird in der Theorie mentaler Modelle postuliert (vgl. Perrig & Kintsch, 1985). Auf der höchsten, der begrifflichen Repräsentationsebene finden Operationen statt, die als höhere geistige Prozesse bezeichnet werden. Sie sind der Ebene mit symbolischen Einträgen (Vorstellung, Wort) übergeordnet. Die Inhalte der begrifflichen Ebene sind von den individuellen Erfahrungen geprägt (ein Wort z.B. kann unterschiedliche Bedeutung haben, in Abhängigkeit von Erfahrung, welche alle Wissensaspekte abdeckt). Daraus resultieren dann verschiedene Arten des Verhaltens. Die Ebene der Begriffe erfüllt außerdem die Aufgabe, als "vertikale Knoten" die Verbindungen zwischen den Repräsentationsebenen herzustellen. Auf den mentalen Ebenen mit symbolischen Einträgen werden Repräsentationen vermutet, welche keine perzeptiven Komponenten besitzen. Die Prozesse folgen nicht notwendig den Regeln der sensorischen Systeme (vgl. Engelkamp & Denis, 1990).

Offensichtlich handelt es sich um keine statischen Abbilder, sondern um dynamische Informationsverarbeitungssysteme. (Die Repräsentationen und die Operationen bilden zusammen ein System).

Die Zusammenhänge zwischen den Repräsentationensformen sind relational und können sich durch den Lernprozess verändern (vgl. Engelkamp & Denis, 1990).

Bei einer intentionalen Bewegung erfolgt die Informationsaufnahme durch mehrere Wahrnehmungssysteme aus dem propriozeptiven wie auch aus dem exterozeptiven

Bereich. Wieviele Ebenen kann man bei der Repräsentation einer intentionalen Bewegung annehmen und welche Eigenschaften muß eine solche Repräsentation besitzen? Eine motorische Fertigkeit kann man als einen Komplex von motorischen Aktionen betrachten, welche auf das Erreichen der vorgesehenen Ortswerte gerichtet sind. Der Ausdruck "Ortswert" ist ein aus der Systemtheorie ausgeliehener Ausdruck (vgl. Hajos, 1989). Die Ortswerte sind die Mediatoren von Konsequenzen. Besteht eine Übereinstimmung zwischen dem geplanten Ortswert und dem Ergebnis der motorischen Aktion, wurde die Zielkonsequenz erreicht und der nächste Ortswert wird angestrebt, bis die ganze motorische Fertigkeit abgeschlossen ist. Der Ortswert wird aus dem funktionellen Zusammenhang der jeweiligen Situation bestimmt. Dabei kommt es nicht auf spezifische Auswahl von Muskelaktivität an, sondern auf die Wirkung. Der Ortswert stellt eine funktionale Größe dar. Die entsprechende Repräsentation wird in der Psychologie als Lokalisation bezeichnet (vgl. Stelmach, 1978). Die Annahme einer hierarchischen Struktur der Repräsentation einer intentionalen Bewegung scheint auf Grund der Überlegung begründet zu sein, daß für eine Bewegungsplanung ein regulatives Wissen erforderlich ist, und andererseits, daß nicht alle Regulationsprozesse bewußtseinsfähig sein müssen (vgl. Stadler, Schwab & Wehner, 1978). Es scheint, daß auf unteren Repräsentationsebenen Prozesse ablaufen, welche dazu dienen, sensorisch-motorische Vorgänge zu simulieren. Diese Repräsentationen können nur so global sein wie die Wahrnehmungen, aus denen sie entstanden sind (vgl. Foppa & Groner, 1991).

Ebene	*Merkmal*	*Funktion*	*Steuerung*
Begriffe	**Bedeutung**	**Gesamtbild Bewegung in der Umwelt**	**kognitiv Raum und Zeit Steuerung**
symbolische Einträge	**Einzelaspekte Bewegung und Umwelteinflüsse**	**Operationen**	**explizit**
nicht berichtbares Wissen	**Nachwirkung der Erfahrung**	**spezielle Operationen und Transfer**	**implizit explizite Nutzung**
propriozeptive Komplexe **propriozeptive primäre Repräsentation**	**Bewegungs-gefühl** **Antagonisten Synergisten**	**Koordination (Synergien)** **Muskelaktivität**	**Reafferenz-prinzip** **implizit**

Abbildung 2. Modell der Repräsentation einer intentionalen Bewegung.

In dem Modell wird u.a. postuliert, daß die Wirkung nicht auf allen Ebenen bewußtseinsfähig sein muß. Das soll aber nicht heißen, daß die bewußten Aktivitäten keinen Einfluß auf solche, dem Bewußtsein nicht zugängliche Ebenen ausüben.

Auf jeder Ebene der Repräsentation werden Parameter definiert, welche die motorische Aktion auf das Erreichen des jeweiligen Ortswertes steuern. Die Parameter verschiedener Repräsentationsebenen müssen aufeinander abgestimmt werden. Die eingegangenen Informationen unterliegen spezifischen Transformationen, welche der jeweiligen Repräsentationsebene entsprechen.

An der hierarchischen Anordnung der Repräsentationssysteme scheint sich eine bestimmte Analogie mit der Struktur des ZNS zu zeigen. Die hierarchische Struktür der Repräsentationen scheint so organisiert zu sein, daß auf den unteren Ebenen Prozesse ablaufen, welche motorische Prozesse simulieren. Auf der niedrigsten Ebene läßt sich eine Repräsentation von einzelnen propriozeptiven Eingängen vermuten. Die Repräsentationen auf dieser Ebene sind allem Anschein nach modalitätsspezifisch. Auf der nächsten Ebene ist die Annahme von komplexen propriozeptiven Mustern denkbar. Die Ebene des propriozeptiven Komplexes ist aus mehreren Elementarspuren zusammengesetzt. Seine Aufgabe könnte es sein, die Aktivitäten der ganzen neuromuskulären Synergie zu regulieren. Eine kognitive Kontrolle ist auf dieser Ebene kaum vorstellbar, denn ein koordinierter Bewegungsablauf enthält u.a. auch solche Muskelaktivitäten wie das Aufrechterhalten des Gleichgewichts bei der Verlagerung des Schwerpunktes, oder die Zusammenarbeit der Antagonisten. Es wird angenommen, daß die Ebenen mit propriozeptiven Inhalten implizit bleiben, weil ihnen symbolische Einträge fehlen. Der Verlauf einer intentionalen Bewegung kann sich in seinen Merkmalen vom kognitiv erfaßbaren Wissen grundsätzlich unterscheiden. Nicht alle mentalen Repräsentationen müssen mit symbolischen Einträgen belegt werden und damit bleiben sie implizit. Auf ihre Existenz kann man auf Grund ihrer Wirkung schließen. Dieses implizite Wissen kann durch Verhaltenseffekte bedeutend sein (vgl. Perrig, 1990, S. 245). Eine explizite Nutzung kann z.B. auch beim Nachdenken oder bei der Planung zum Vorschein kommen (vgl. Wippich, Mecklenbräuer, Wentura & Stümpel, 1991, S. 127). Im Schema ist die Ebene des nichtberichtbaren Wissens (vgl. Foppa, 1990) als eine eigenständige Ebene der Repräsentation dargestellt (Abbildung 2).

Dieser implizite Charakter kann auch nur vorübergehender Natur sein (vgl. Foppa & Groner, 1991). Es handelt sich um eine mentale Repräsentationsform, welche solange implizit bleibt, als ihr symbolische Einträge fehlen. Auf den höheren Ebenen befinden sich Repäsentationen mit symbolischen Einträgen. Diese Ebenen weisen größere Komplexität auf. Die zwei höchsten Ebenen sind nach unserer Vorstellung mit symbolischen Einträgen belegt und damit kognitiv steuerbar. Der Unterschied zwischen den beiden Ebenen liegt in individuell bedingter Erfahrung und Kenntnissen, welche auf der Ebene der Begriffe u.U. ungleiche Inhalte mit gleicher Benennung vermuten lassen. Diese Repräsentationen sind von individuellen Erfahrungen geprägt, und die Prozesse verlaufen nicht mehr nach den Regeln der sensorischen Systeme. Außerdem wird auf dieser Ebene die Existenz von Verbindungsknoten für die koordinierte Zusammenarbeit aller Repräsentationsebenen postuliert. Die Aspekte einer intentionalen Bewegung belegen mehrere Ebenen der Repräsentation. Durch Operationen können alle Aspekte, die zu einem Ereignis gehören, aktiviert werden und das Wiedererkennen des Ereignisses hervorrufen. Eine Kopie des Ereignisses hat die Funktion eines rezeptiven Regulators. Wenn aber die propriozeptiven Aspekte eine bestimmte Dominanz erreicht haben, erhöht sich damit die Wahrscheinlichkeit, daß die Kopie für die Bewegungsproduktion funktional wird. Diese Situation ist bei der Respräsentation einer intentionalen Bewegung praktisch immer erreicht. Selbstverständlich verlieren die Repräsentationen mit symbolischen Einträgen damit keineswegs an Bedeutung. Die Kognitionen sind für die antizipatorischen Prozesse und für die Steuerung des Bewegungsverlaufes unerläßlich. Durch Operationen auf den symbolisch belegten Ebenen wird die zeitliche und die räumliche Organisation der Ortswerte bestimmt und damit werden die Parameter Zeit und Raum des Bewegungsablaufes definiert.

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REPRESENTATION OF MOVEMENT SPEED IN DANCE BY NOVICES

MARIELLE CADOPI, FRANCE

Introduction

Dance, figure skating, rhythmical and sports gymnastics, synchronized swimming, and diving all have one specific feature in common: participants in these activities must present corporal sequences or routines (attitudes, figures) to spectators or judges who evaluate and rate their performance. To teach these figures, ballet teachers and other trainers rely heavily on demonstrations accompanied by verbal explanations.

Our aim was to determine what novices do when faced with a demonstration of a corporal routine or sequence, and more precisely, what role is played by the representation they make of what they learn. In his analysis of the representative control of performance, Chatillon (1988) compares the acting subject to "a machine for producing actively sought results". The subject's activity can be understood as the result of the coordination of two functionally different generators. The first, called the act generator, works in real time "under the pressure of directly perceived events" (Piaget, 1936) and/or under the effect of their representations (Chatillon, 1988). The second, called the plan generator, works in real time and/or in deferred time, and is responsible for the production of representations that serve as a reference for current or future actions. These internal models are written in a language made up of differentiated signifiers (words, images, symbols). They result from the "topicalization" of the task by the subject, and necessarily involve information about the goal of the task, and perhaps also some information about the potential means of attaining that goal. Thus, the processes and output of these two generators, in conjunction with information from other sources (e.g. the properties of the biomechanical system), contribute to controlling performance.

A dancer's control of his/her performance depends on the type of task, his/her degree of expertise, and the style of dance. The nature of the coordination required to incorporate information from the various potential sources varies, and in particular, the extent to which representative control is implicated is highly variable. This problem will be analyzed here for novices rehearsing a new routine. The newness of the routine, in addition to the subjects' lack of expertise, force them to build the most complete representation of the routine possible. This representation has a bearing both on a dancer's ability to reproduce the sequence, and on his/her ability to representation has a bearing both on a dancer's ability to reproduce the sequence, and on his/her ability to interpret and assess his/her own execution or that of another dancer, with the minimal number of errors. It serves as an internal model for action, and varies highly across individuals, age groups, and skill levels. At the very least, it contains information about the sequence of movements (the goal to be reached), and may also include some means of attaining that goal. Because it is an internal model for action, it is a functional representation (Leplat, 1985). Its function is to assimilate the data acquired about reality. But the type of assimilation it allows is more or less distorting, and hence, a source or error. Errors in a subject's performance are thus the expression of the properties of the underlying internal model. This fact can be used to study the dancer's representation from an ecological standpoint, since it falls within the bounds of the subject's normal functioning. This analysis is similar to the one proposed by Leplat (1989), who stated that "correct action and errors are two sides of the same coin. Error is not only defined negatively — in terms of deviation from the goal, or non-accomplishment of the task — but also as the product of an activity whose mechanism must be discovered."

To obtain the desired result, subjects use information drawn from the outside world — the device (here, the routine), the instructions, the context in which the task is requested (Leplat & Pailhous, 1978) — and internally, from previously acquired knowledge. The latter is the product of their stage of cognitive development and past learning. It provides them with an entire set of essential data for organizing and controlling the execution of the task. These are the "anterior schemes" referred to by Piaget (1974). Available knowledge and know-how thus fulfill multiple functions: the organization and programming of acts or thoughts, task recognition, selection of useful data for execution, etc. They constitute the basic framework from which the subject can form new actions whenever the situation requires it. In this set of data, Piaget (1947) distinguished two categories of schemes: (1) The first is composed of action schemes evoked by and within the subject's dialogue with reality, i.e. during the action. (2) The second is made up of thought representation schemes. Like action schemes, thought schemes are evoked in real-time, but they are also brought to bear in deferred time, i.e. when no immediate action is required. When implemented, the latter type of scheme acts as a source of information for preparing and controlling action. In dance, as in other related activities, this source plays an important part in learning a new routine, for both novices (Fitts, 1964) and experts.

Thus, when subjects are asked to detect deviations from a model memorized in view of later recognition, analysis of their judgments, and their subsequent explanations of those judgments, should inform us about what subjects represent and how they represent it. Given the above, we can hypothesize the following: (1) subjects' representations can be expected to differ according to their stage of development, and (2) the representation of differences in movement speed should not appear until about age 10, when subjects are able to form kinetic images (Piaget & Inhelder, 1966).

Method

Sample

The sample was composed of five independent, sex-balanced groups of twenty-four subjects, age 6, 8, 10, 12, and 20 years (± 6 months). None of the subjects had ever danced.

Procedure

Each group learned a model routine in view of later recognition. The subjects' judgments of conformity to the model and their accompanying explanations were analyzed.

The model routine, which consisted of five steps, was performed by an advanced dancer (cf. Figure 1). It was recorded 20 times in succession on a videotape, so that the subjects could play back as many performances as desired during the learning period.

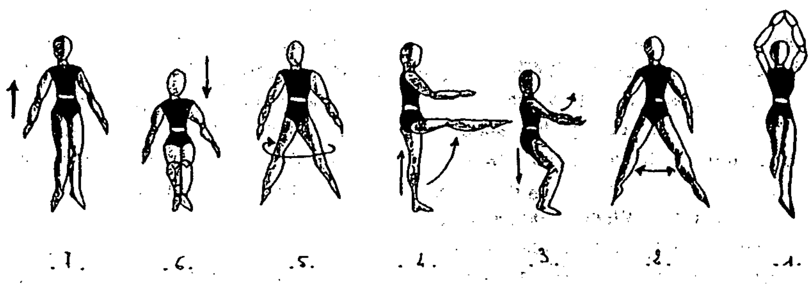

Figure 1. Model routine.

The test sequences consisted of the model routine and five test routines, one of which differed from the model in exactly one manner: one of the steps was executed four times as slow. Four test sequences each containing 6 routines were obtained by combining the model routine and the five test routines in random order.

Task

The standard form of the instructions (which was adapted to the subjects' comprehension level) was as follows:

> I'm going to show you a short film of a girl dancing. Watch it carefully, because you have to learn the dance so you can recognize it if I show it to you again later. You can watch it as many times as you like. When you think you know it well, tell me. Then I'll show you some other short films in which the same girl is dancing. You will be asked to tell me whether she is doing the same dance as the one you learned. If you think it's not the same dance, then tell me so and explain why. The camera filming her does not move. Now can you tell me what you're supposed to do?

The model was shown until the subjects felt they knew it well enough to recognize it. Then the 6-routine test sequence was shown.

Results

The results are presented in Figure 2.

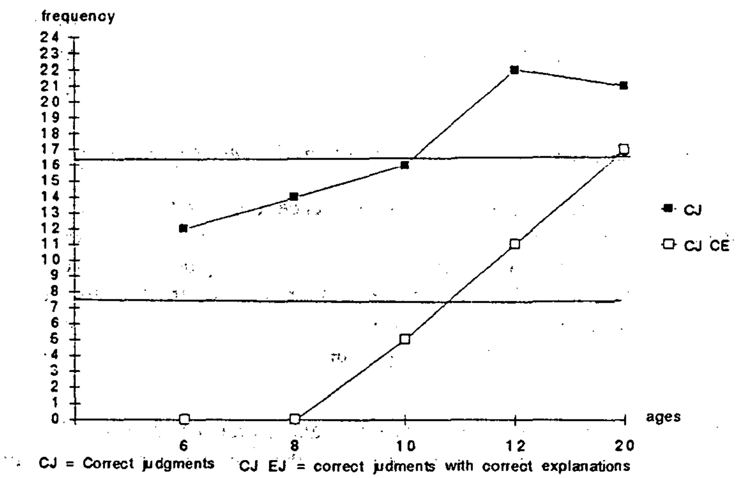

Figure 2. Number of correct judgments and number of correct judgments accompanied by correct explanations, by age group.

Correct Judgments

A judgment was considered correct when a subject stated that the test routine was different from the model, and incorrect in the opposing case.

Correct judgments increased with age. To determine whether this observation was the manifestation of a tendency to always give the same answer, or whether the same result would be obtained with a group of subjects responding at random for two equiprobable outcomes (correct judgment/incorrect judgment), i.e. $p=q=.50$, the 24 responses were treated as 24 independently drawn subjects to the hypothesis of response equiprobability (binomial test, Siegel, 1956). This reasoning was applied to all of the results obtained. Two lines parallel to the x-axis are thus shown on the graph in the Figure 2: line L1 defines the limit at $\alpha=.05$ with $N=24$ separating area 1, where less than half of the subjects in the group produce a correct judgment (with $p=q=.50$) from area 2, where one out of every two subjects responds correctly. Likewise, line L2 defines the limit at $\alpha=.05$ with $N=24$ separating area 2 from area 3, where more than half of the subjects respond correctly. One can determine directly from the graph whether or not the results obtained differ significantly from the outcome of a random drawing.

The graph in Figure 2 shows that one out of two subjects in age groups 6, 8, and 10 responded correctly. Also, a significantly greater number than one out of two subjects in age groups 12 and 20 responded correctly. The conclusion that may be drawn is that the tendency to judge correctly became systematic by age 12.

Correct Judgements Accompanied by Correct Explanation

Subjects who correctly judged the test sequence could either give a correct explanation of their answer, an incorrect explanation, or no explantion. Explanations were considered correct when they pointed out the existence, location, and nature of the difference between the model and the test (for example, "It's not the model because right here, it's slower"). Hereafter, correct judgments accompanied by correct explanations will be compared to the other types of responses.

Figure 2 shows that no subjects in age groups 6 and 8 produced a correct judgment with a correct explanation. After age 8, the number of correct judgments/explanations increased. In the age group 10, significantly less than 1 out of 2 subjects came up with a correct explanation for a correct judgment, and in the age group 12, one out of two subjects did so. In the age group 20, significantly more than one out of two gave a correct explanation.

These results did not provide evidence of a systematic tendency to make a correct judgment and give a correct explanation before age 12. However, this tendency was significantly above the chance level by age 20. Hence, subjects of different ages respond differently.

Changes in Number of Correct Judgments and Number of Correct Judgments/Explanations with Age

Figure 2 shows that the age-by-response curves for the correct judgments variable and the correct judgments/explanations variable are more or less parallel. Note also that more than half of the subjects made correct judgments when the ability to give a correct explanation had been acquired; this occurred at age 12, as if subjects become capable at that age of "thinking about speed". Note finally that the distance between the two curves began decreasing at age 10.

Discussion

When a subject performs a task, he/she may or may not be able to produce the desired result, and in each case, may or may not be able to explain why. In the present experiment, the criterion for success of a given group of subjects was their ability to detect a difference in speed between the model and test routines. In addition to judgment success, correct or incorrect explanations for those judgments could be given. A given subject was said to understand why the test routine was not like the model when he/she produced a correct explanation following a correct judgment. This type of response indicates that the internal representation of the model constructed during observation, and subsequently used to perform the recognition task, must contain precise information about the speed of the movements in the routine under study. For other types of responses (for instance, correct judgments with no explanation or with an incorrect explanation), either the internal model contains no speed information, or the information it contains is not usable by the child's explanatory processes. Thus, these results demonstrate that the ability to make and explain correct speed judgments is highly dependent on developmental stage.

The tendency to make a correct judgment did not become significantly greater than chance until age 12 (at age 10, the tendency was clear, but nonsignificant).

In age groups 6, 8, and 10, the tendency to give a correct explanation was significantly lower than chance. In fact, none of the 6- or 8-year-olds were able to do so. Correct and incorrect explanations were equiprobable for the 12-year-old group. The 20-year-olds gave correct explanations significantly more often than by chance.

The difference between the number of correct judgments and the number of correct judgments accompanied by correct explanations was found to decrease with age. This decrease is mainly due to the fact that the number of correct explanations increased, while the number of correct judgments reached a ceiling. This effect was particularly strong for the 20-year-olds. These results raise the issue of the nature and content of the internal model constructed by subjects confronted with this task, and can be discussed in two frameworks:

(1) Studies on the development of mental images have shown that by the age of 8 or 10, subjects are able to form kinetic images (Piaget & Inhelder, 1966). Our results suggest that subjects encode the model routine in image format, not in verbal format. This interpretation is consistent with Annett's (1985) contention that it is easier to encode motor actions in image format than in verbal format.

(2) Our results can also be considered in the light of current knowledge about the development of kinesthesic perception, which again raises the question of the link between action and perception. Redon, Rigal, Hay, Roll, and Demaria (1991) analyzed the role of proprioceptive afferences of muscular origin in the perceptual coding of movement speed in 5-, 7-, and 9-year-olds performing tasks involving the reproduction of real and illusory movements of the forearm (tendon vibration technique). These authors found that the youngest children tended to reproduce movements by exaggerating their speed. Young children are also known to be incapable of voluntary execution of very slow movements (Costantini, Corsini, & Davis, 1973; Rey, 1968); they live, so to speak, in a universe of relatively high speeds. This may[1] be one of the reasons why 6-year-olds cannot represent a difference in speed when it involves the slowing down of a movement, as in our experiment.

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ANALYSIS OF REPRESENTATIONS AND PATTERNS OF TACTICAL DECISIONS IN TEAM GAMES

A METHODOLOGICAL APPROACH

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Introduction

The efficiency of the strategies selected by the player constitute the main criterion of skill acquisition. It seems that the formation of skills is widely based on the transformation of strategies according to the task requirements and to the subject's use of his own resources (Kay, 1970; Knapp, 1975; Welford, 1977).

The analysis of the strategies demonstrated by outstanding players and of the conditions of the operation of these strategies is thus critical. However, strategies are not directly accessible to common observation, and it is suitable to be more precise about the specificity of game sports, in order to define the main conditions of a profitable analysis of such opposition sports situations.

1) The development of skills in team games stems from the consideration of required adaptability to the fluctuating attacker/defender interaction (Figure 1).

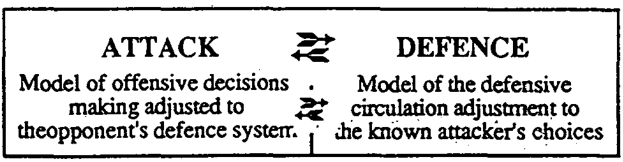

Figure 1. Model of interaction attacker/defender (Deleplace, 1979).

2) The activity of team sports player is made intelligible not only through the action he is temporarily involved in, but also through the cognitive system of reference made up by the more or less complete, relevant and precise mental representation of the system of which he is an active element (Figure 2).

The construction and operation of models remains on the elaboration of symbolic systems which are halfway between the empirical field and the sphere of theoretical models.

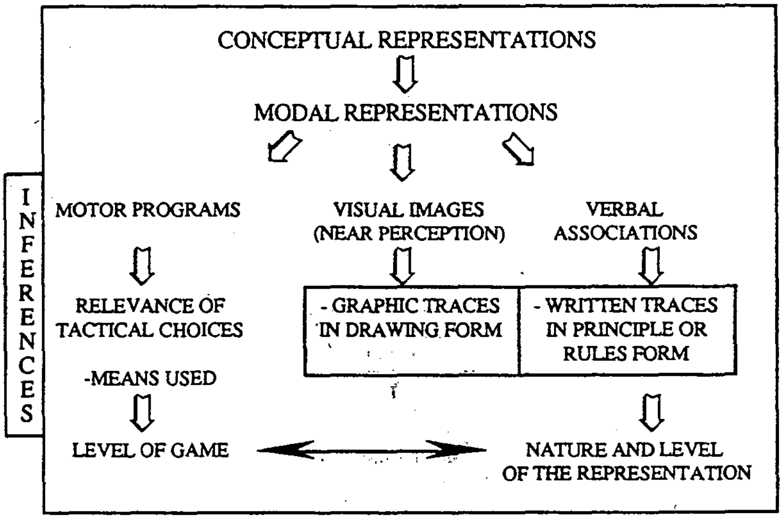

Figure 2. Levels of representations and actions (David, 1987, according to Denis, 1990; Engelkamp & Zimmer, 1985; Paivio, 1986).

These systems are both relatively isolable from the empirical field and consistant with some levels of the models. They therefore make possible a two-way circulation between the variables of the models and their actual values observed during practice (Walliser, 1977). They allow to modify, correct, validate models which are first descriptive, then become progressively predictive thanks to the possibilities of simulation they offer once they are settled.

The cognitive psychological theories have the status of a scientific discipline used for the study of sport didactics. In the following examples, we present a didactical model of decision taking in volleyball, and methodological elements of the analysis of representations and actions in rugby.

Graphic Representation of a Tree of Decisions in 2 vs 2 Volleyball Situation

This representation displays the linking of the enchainement of cognitive operations which constitute the tactical choice. It enables the teacher to detect the procedural mistakes which prevent the pupils to reach the ideal solution. It constitutes the teacher's referential.

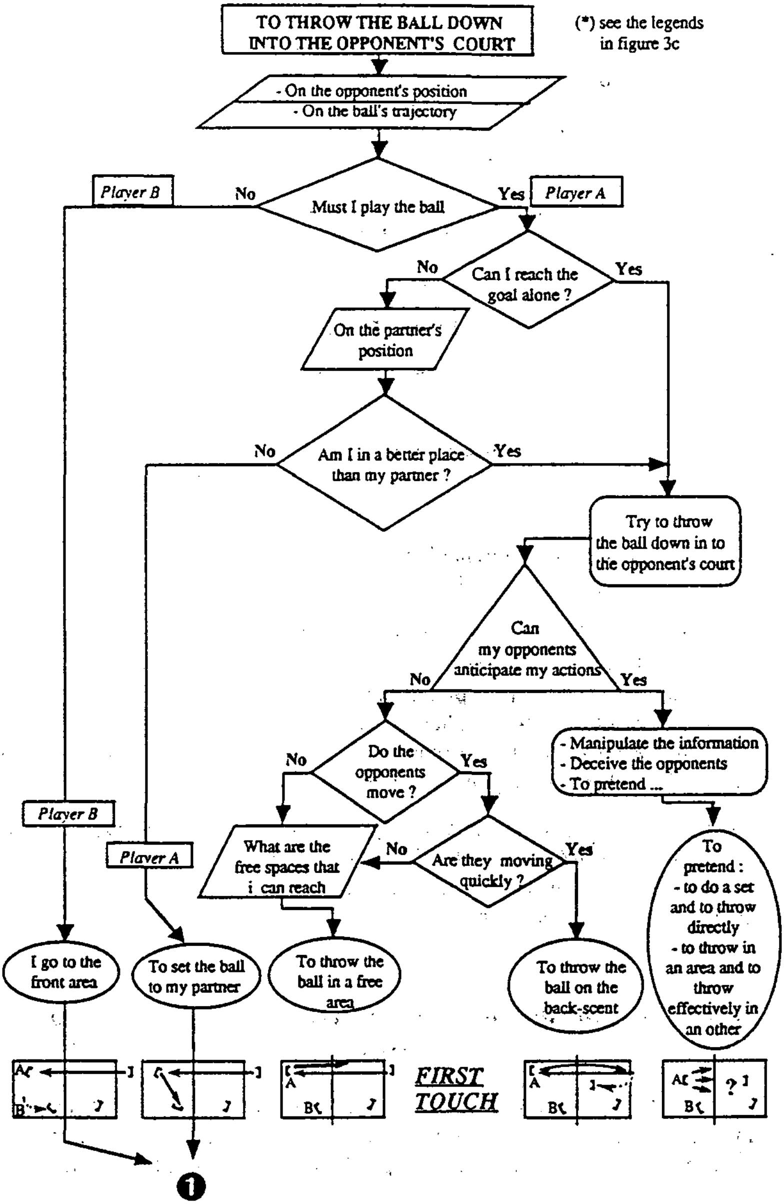

Figure 3a. Tree of decision-model in 2 vs 2 volleyball situation: First touch.

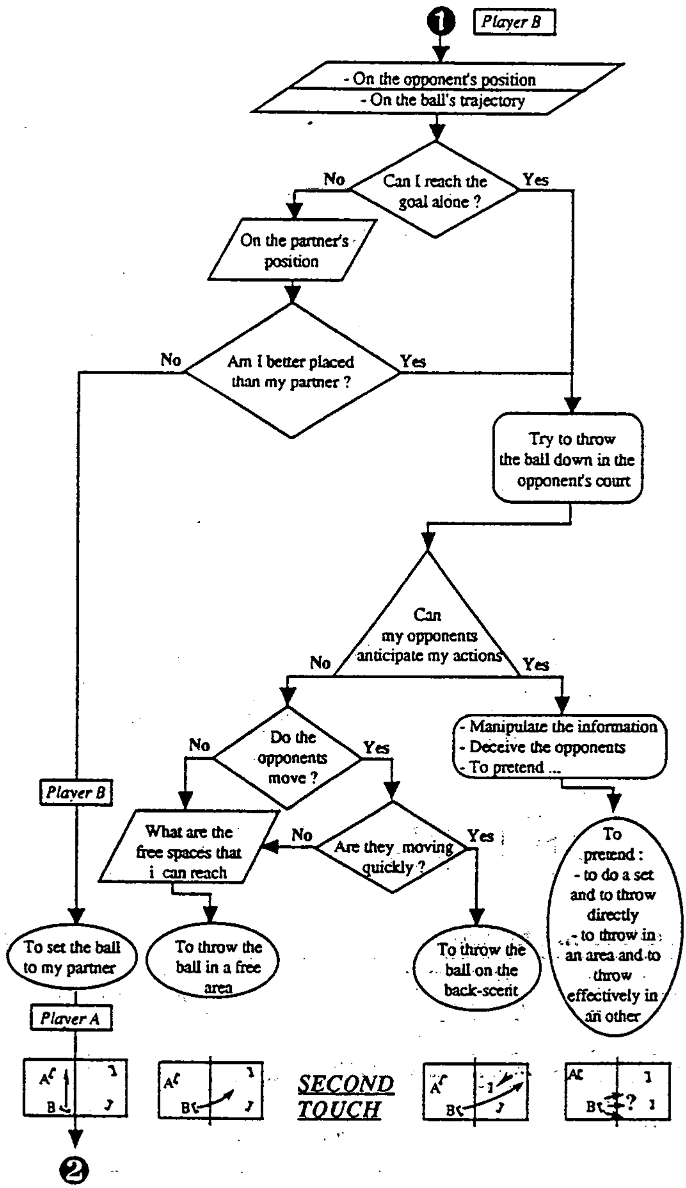

Figure 3b. Tree of decision-model in 2 vs 2 volleyball situation: Second touch.

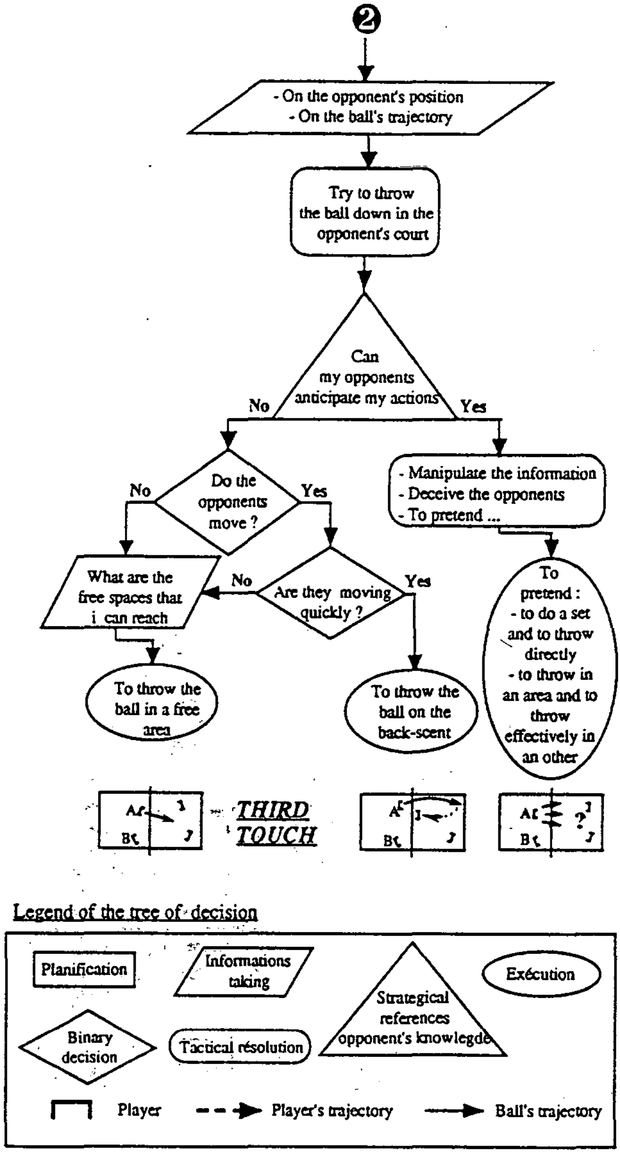

Figure 3c. Tree of decision-model in 2 vs 2 volleyball situation: Third touch.

All activity is oriented by a goal. In Volleyball the goal (of a game) is to get the ball to touch the floor in the opponent's court.

The choice of a future solution has to result from an information uptake about:

- The ball: speed, trajectory,...
- The opponents: positions, orientations, displacements,...
- The team mates: positions, orientations, displacements,...

This information taking process must determine the player's decision and action. In order that the players on the same team make the same analysis of the situation, it is necessary that they share an identical functional representation of the situation (common referential). A simplified tree of decisions presented to beginners contributes to this objective and allows the player who does not receive the ball to anticipate his future action (Figure 3a, 3b, 3c).

Representations of Actions of the Rugby Player

- The rugby player groups are tested in the spread out 5 vs 5 standard situation.
- The defence is manipulated (open, closed, flat or anarchic) so as not to lock up the attack in a stereotyped way and oblige attacking players to produce tactical choices in a very uncertain context almost as in the real game situation (cf. Bouthier & Savoyant, 1984).
- The groups work under identical experimental conditions (cf. Figure 4, Figure 5).
- Graphic traces are gathered with the help of a simply and easily handled questionnaire. It produces several caracteristic situations of a deployed game, the way out of attacking and defending on a momentabily threatered space.
- Each situation must be solved following the written or drawn modality, or both, under time pressure and following a precise protocol.
- The categories of the following analysis are:

Tactical choices at the crucial point :

- Right choice
- Wrong choice
- Non typical choice

Means used by the players:

- Passage by percussion, impact
- Individual escape
- Siding game
- Foot service

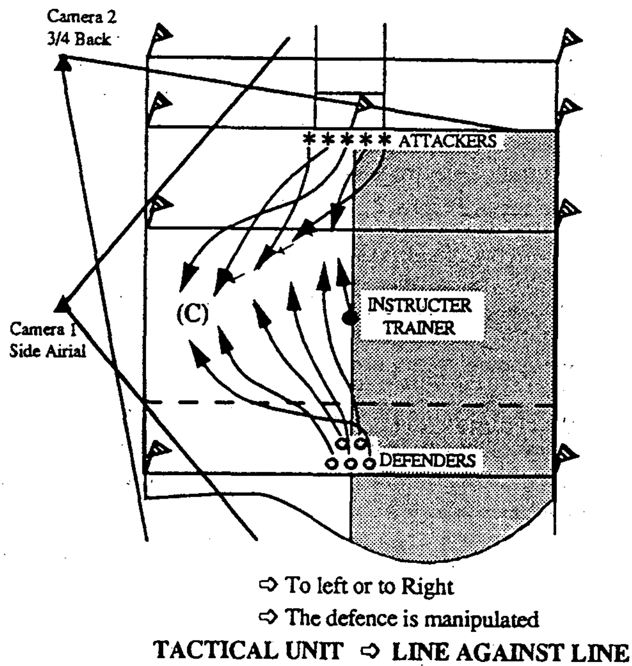

Figure 4. Material arrangement.

The categories have the advantage to be useful for the picking of informations about the real tactical actions and the analysis of graphic inferences.

In order to conceive the formation of players in tactical decision making, it seems important to modify act on the couple abstract structure and material arrangement of the action.

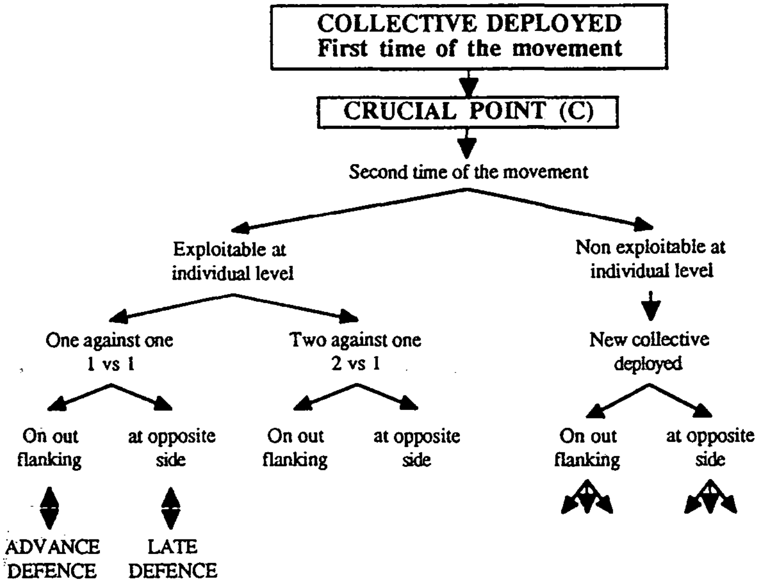

Figure 5. Abstract structure.

The intervention on the abstract structure aims at the transformation of the individual initial representations to construct a common referential rationale for collective actions (indications of tactical class problems, choice criterions of solutions, principles of execution). It supposes also to improve the study of the nature and levels of representations and of the most efficient ways to present informations.

The concrete structure of action must simulate real playing situations preserving their specific caracteristics (alternative solutions attack/defence reversibility, target and space in relation with level and number of opposite players)

It allows to skip the classic motor tasks analysis regenerating the meaning of the action in reference to the social dimension of activity.

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Psychologische und biomechanische Analyse des Skisprungs unter Simulationsbedingungen

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Einleitung

Im Rahmen eines interdisziplinären Forschungsprojektes wurde u.a. ein Untersuchungsdesign speziell für die Sportart Skisprung entwickelt und getestet, mit dessen Hilfe Informationen über die kognitive Repräsentation von bestimmten Bewegungsparametern bzw. Phasen der Gesamthandlung (hier Anfahrt und Absprung) erfaßt werden sollen.

Um den zeitlichen und dynamischen Verlauf der Anfahrt- und Absprungphase einer bestimmten Schanze im Labor zu simulieren, wurden sowohl der Kraft- als auch der Geschwindigkeitsverlauf auf der Basis von im Feld erhobenen biomechanischen Meßwerten in akustische Signale umgesetzt. Trainer beurteilten die im Experiment realisierte akustische Umsetzung einer Kombination von Kraft- und Geschwindigkeitsverlauf als eine nahe am realen Ablauf liegende Darbietung des subjektiven Bewegungseindrucks.

Methode

Versuchsaufbau

Die Versuchsanordnung besteht aus einer Kistler-Meßplattform und einem Rechner zur Sollwertvorgabe (mittels Tonfrequenzmodulation) sowie zur Datenerfassung und -aufbereitung. Der Kraft-Zeit-Verlauf der Sprungbewegung wird auf dem Bildschirm graphisch dargestellt. Eine graphische Darstellung der Sollwertvorgabe kann mit dem Kraft-Zeit-Verlauf überlagert werden. Versuchsleiter oder Untersuchungsteilnehmer können auf diese Weise Informationen über Soll-Ist-Diskrepanzen erhalten.

Bewegungsaufgabe

Die Bewegungshandlung, die die Teilnehmer auszuführen hatten, läßt sich folgendermaßen beschreiben:

Die Versuchsperson sitzt in der Ausgangsposition auf der Kante eines Tisches, wobei die Füße Kontakt mit der Kistler-Meßplattform haben. Auf ein Startsignal hin stößt sie sich von der Tischkante ab und nimmt auf der Meßplattform so schnell wie möglich eine der Skisprung-Anfahrt entsprechende Hockposition ein. Es folgt dann der eigentliche Squat-Jump, der ohne aktiven Armeinsatz auszuführen ist. Die zeitliche Sollwertvorgabe (Dauer der Tonfrequenzmodulation) beträgt 5 sek.

In Abhängigkeit von der Versuchsphase und den Versuchsbedingungen (s.u.) ergeben sich zwei Arten der zeitlichen Sollwertvorgabe. Bei paralleler Sollwertvorgabe erhält die Versuchsperson mit Startbeginn das akustische Signal und hat die Aufgabe, die Bewegungshandlung zeitgleich mit dem Ende des Signals abzuschließen. Bei getrennter Sollwertvorgabe erhält die Versuchsperson vor der Bewegungshandlung den Sollwert vorgegeben. Anschließend ist die zeitlich-dynamische Vorgabe für den Ablauf der Bewegungshandlung beim Ausführen aus dem Gedächtnis zu reproduzieren.

Versuchsgruppen

Die Untersuchungen bauen auf einem zweifaktoriellen Design auf, wobei neben dem Faktor Sollwertvorgabe (getrennte bzw. parallele Sollwertvorgabe) der Faktor Feedback (verbal-auditives bzw. visuelles Feedback) ausgewählt wurde. Daraus resultieren in den entsprechenden Untersuchungsphasen vier Gruppen.

Die Versuchsgrüppen wurden auf Basis der Ergebnisse eines ersten Untersuchungstermins bzgl. der Leistungsmerkmale Genauigkeit der zeitlichen Reproduktion von Sprungbewegungen und des Schnellkraftindexes parallelisiert.

Versuchsablauf

Die Untersuchungen liefen als Einzelversuche im Labor des Psychologischen Instituts der Deutschen Sporthochschule Köln. Jede Versuchsperson nahm an jeweils zwei Terminen teil, die ca. eine Stunde dauerten. Die Untersuchungen wurden von zwei Versuchsleitern durchgeführt.

Das Untersuchungsdesign des zweiten Termins (Hauptuntersuchung) ist in Abbildung 1 dargestellt.

Untersuchungsdesign

Aufwärmen inklusive 3 Probesprüngen

5 Sprünge mit paralleler Sollwertvorgabe (Gruppe A)	5 Sprünge mit getrennter Sollwertvorgabe (Gruppe B)

- Kurzbefragung nach jedem Sprung

5 Sprünge mit paralleler Sollwert-vorgabe; visuelles Feedback (A, visuell)	5 Sprünge mit paralleler Sollwert-vorgabe; auditives Feedback (A, auditiv)	5 Sprünge mit getrennter Sollwert-vorgabe; visuelles Feedback (B, visuell)	5 Sprünge mit getrennter Sollwert-vorgabe; auditives Feedback (B, auditiv)

Interview

3 Sprünge ohne Sollwertvorgabe
(Reproduktion des Ablaufs aus dem Gedächtnis)

- Kurzinterview zu den letzten 3 Sprüngen

Abbildung 1. Untersuchungsdesign der Hauptuntersuchung.

Alle Gruppen führten nach einer Aufwärmphase 3 Probesprünge aus. Ggf. wurden hier noch einmal technische Korrekturen vorgenommen. Es folgten dann 5 Sprünge mit paralleler oder getrennter Sollwertvorgabe. Alle Teilnehmer hatten nach jedem Sprung einzuschätzen, wie ihnen die Sollwertrealisierung gelungen war. Danach waren 5 Sprünge auszuführen, für die nach der Selbsteinschätzung durch die Teilnehmer vom Versuchsleiter entweder verbal-auditives oder visuelles Feedback bzgl. der zeitlichen Genauigkeit des Timing-Vorganges gegeben wurde. Für alle Untersuchungsteilnehmer folgte ein kurzes Interview zur Erfassung interner Repräsentationen. Die Teilnehmer sollten dann drei Sprünge ohne Sollwertvorgabe und ohne Feedback aus dem Gedächtnis möglichst genau reproduzieren. Die Untersuchung wurde mit einer Kurzbefragung zu den letzten drei Sprüngen abgeschlossen.

Versuchspersonen

An der Untersuchung nahmen 35 männliche Sportstudenten der Deutschen Sporthochschule mit einem Alter zwischen 23 und 29 Jahren teil. Die Teilnehmer hatten Schwerpunkte in unterschiedlichen Sportarten, keine Vorerfahrung im Skisprung und wiesen unterschiedliche Übungsleiter- oder Trainertätigkeiten auf.

Ausgewählte Ergebnisse

Zeitliche Genauigkeit der Bewegungsreproduktion

Der Einfluß unterschiedlicher Sollwertvorgaben und Feedbackbedingungen auf die zeitliche Genauigkeit der Bewegungsrepräsentation kann anhand der Ergebnisse der Sprünge 11-13 in der Hauptuntersuchung überprüft werden. Alle Gruppen hatten hier die Aufgabe, aus dem Gedächtnis den Bewegungsablauf zeitlich genau zu reproduzieren. Als Fehlermaß wird die absolute Abweichung der Bewegungsdauer vom Sollwert herangezogen.

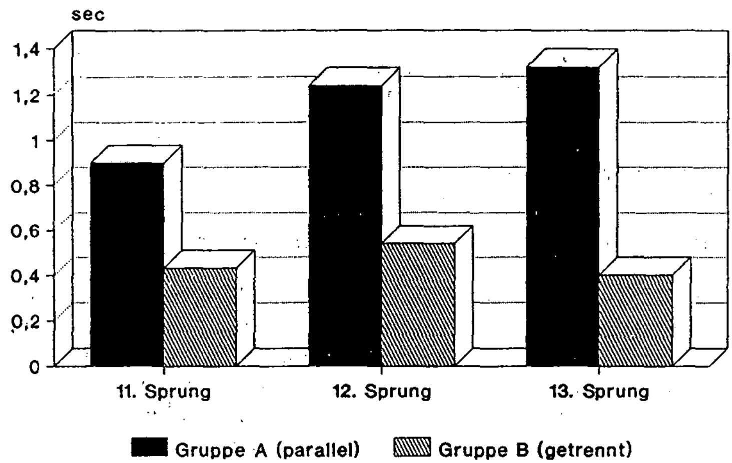

Abbildung 2. Absoluter Fehler bezogen auf die Bewegungsdauer (differenziert nach Sollwertvorgabe).

Die Gruppen mit paralleler Sollwertvorgabe in den vorangegangenen Phasen wiesen im Mittel beim 11. Sprung 0.90 sek, beim 12. Sprung 1.24 sek und beim 13. Sprung 1.32 sek Differenz zum Sollwert auf. Die entsprechenden Werte der

Gruppe mit getrennter Sollwertvorgabe lauten 0.43 sek, 0.54 sek und 0.40 sek. Bei allen Sprüngen weisen die Gruppen mit paralleler Sollwertvorgabe deutlich höhere (und statistisch absicherbare) Abweichungen auf, die im Verlauf sogar zunehmen. Die Werte sind in Abbildung 2 graphisch veranschaulicht.

Differenziert man die Ergebnisse weiter hinsichtlich der Feedbackbedingungen, zeigt sich, daß jeweils beide Gruppen mit paralleler Sollwertvorgabe höhere Abweichungen aufweisen als die beiden Gruppen mit getrennter Sollwertvorgabe. Ein wesentlicher Einfluß des Feedback zeigt sich nur bei paralleler Sollwertvorgabe. Hier weist die Gruppe mit verbal-auditivem Feedback größere Abweichungen auf als die Gruppe mit visuellem Feedback. Bei getrennter Sollwertvorgabe ergeben sich keine vergleichbaren Befunde. Die Ergebnisse für die vier Gruppen sind in Abbildung 3 graphisch veranschaulicht.

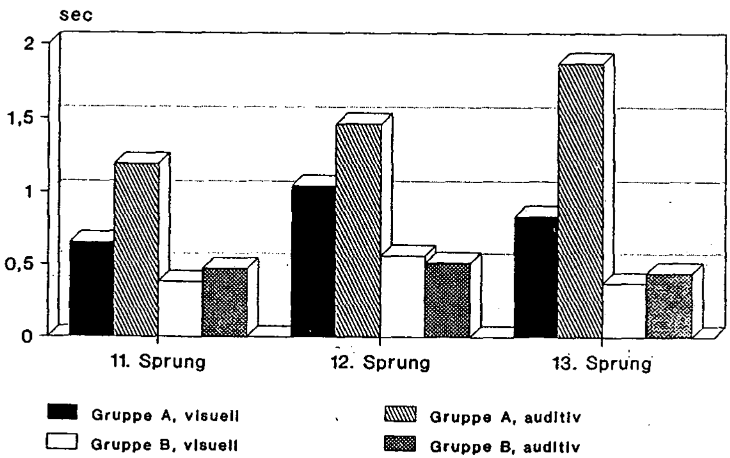

Abbildung 3. Absoluter Fehler bezogen auf die Bewegungsdauer (differenziert nach Sollwertvorgabe und Feedback).

Repräsentation der Zeit und Nutzung der Tonmodulation

Im Vordergrund der Auswertung der Befragungsdaten steht die Frage, welche Rolle die akustische Sollwertvorgabe für die zeitliche Genauigkeit der Bewegungsreproduktion besitzt. Es finden sich eine Reihe von Aussagen, die auf eine positive Wirkung der akustischen Vorgabe schließen lassen. Beispiele dafür sind die Aussagen:

... ich hatte mit dem Ton eine bessere Möglichkeit, mir die Schanzenabfahrt vorzustellen."

"... ja der Ton bewirkt auch, dadurch daß er schneller wird, so ein Gefühl als würdest du da fahren - das kommt dir also wirklich so vor."

"... wenn man den Ton hört, das kommt einem auch aus dem Fernsehen bekannt vor, dieses Geräusch durch den Absprung und die Anfahrtsgeräusche, da konnte ich mir schon diese Schanze oder wie so ein Springer, also mich selbst nicht, aber einen anderen schon, eher vorstellen ..."

In diesen Aussagen wird thematisiert, daß die akustische Vorgabe die Vorstellungsfähigkeit beeinflussen oder zumindest unterstützen kann.

Die Verbindung von Ton und visueller Vorstellung bzw. Krafteinsatz deutet darauf hin, daß das akustische Hilfsmittel unterschiedlich eingesetzt wird und daß sich damit auch unterschiedliche Strategien für den Umgang mit der Zeitproblematik ergeben. Folgende Strategien werden von den Untersuchungsteilnehmern thematisiert:

1. Zählen

2. Hauptsächliche Nutzung des akustischen Systems mit

   - Vorstellen der Tonmodulation
   - Innerer Imitation der Tonsequenz

3. Verbindung von Akustik mit verschiedenen Systemen:

   - Akustische kombiniert mit visueller Vorstellung
   - Akustische kombiniert mit kinästhetischer Vorstellung.

4

Raum-zeitliche Aspekte des Bewegungsverhaltens

Spatial and Time Aspects of Motor Behaviour

WIE ORIENTIERT SICH EIN BLINDER SPORTLER IM RAUM?

HANS-GEORG SCHERER, DEUTSCHLAND

Nach der Befruchtung durch die ökologische Theorie der Wahrnehmung ist die einschlägige psychologische Forschung erneut mit der Aufschlüsselung des Mobilitätsproblems blinder Menschen beschäftigt. Daraus erwachsen auch Perspektiven für die Analyse sportlichen Handelns (vgl. Jansson, 1990; Strelow, 1985).

Sportliches Handeln als zielorientierte Selbstbewegung

Die meisten sportlichen Handlungen sind mit einer Fortbewegung des Akteurs verbunden. Sportliches Handeln soll deshalb zunächst ganz global und ohne Berücksichtigung der je sportartspezifischen Aufgabencharakteristika als zielorientierte Selbstbewegung (amerik. "egomotion") betrachtet werden (vgl. Jansson, 1990; Warren, 1990). Es stellen sich dabei zwei grundlegende Aufgaben:

1) Der sich Fortbewegende muß die räumlichen Relationen seiner Position zu den relevanten Merkmalen seiner Umgebung, zum Ziel und die Relationen zwischen diesen wahrnehmen. Übersteigt der Umfang des handlungsrelevanten Raumes den Wahrnehmungshorizont, so muß die perzeptive Kontrolle durch kognitive Elemente ergänzt werden. Dieser Horizont ist beim blinden Menschen meist eng gezogen.

2) Die Fortbewegung muß in Bezug auf das Ziel und die Umgebungsmerkmale kontrolliert werden. Entscheidend sind dabei Informationen über die Richtung und Geschwindigkeit, sowie über Entfernungen, v.a. bei der unmittelbaren Annäherung an Objekte bzw. Ziele.

Es wird sich zeigen, daß — im Unterschied zum Sehenden — der blinde Akteur diese beiden Teilaufgaben kaum trennen kann und daß Teilaufgabe (1) in der Regel in Teilaufgabe (2) mitgelöst werden muß.

Daß sie bei Blindheit überhaupt lösbar sind, ist erstaunlich, wenn man bedenkt, daß beim Sehenden nahezu alle Informationen für eine erfolgreiche Kontrolle dieser Relationen über das visuelle Wahrnehmungssystem geliefert werden. Ich will hier relevante ökologische Konzepte wie optische Fließmuster, optischer Pol, optische Dichte, Texturgeschwindigkeit oder time-to-contact nur erwähnen (vgl. hierzu Gibson, 1982; Lee, 1980; Warren, 1990). Zieht man nun sportspezifische Aufgabencharakteristika mit in Betracht, so ergeben sich aus "visueller Perspektive" weitere Paradoxa, die das Verhältnis von einfachen und komplexen

Wahrnehmungsaufgaben auf den Kopf zu stellen scheinen. So fällt z.B. blinden Sportakteuren das einfache Geradeauslaufen auf einer großen hindernisfreien Fläche überraschend schwer, während wesentlich komplexere Aufgaben der räumlichen Orientierung beim Schifahren, beim Rhönradturnen oder gar beim Kajakfahren im Wildwasser vergleichsweise gut gelöst werden.

Informationen für Wahrnehmungssysteme — praktische Beispiele

Solche Phänomene verweisen auf die Notwendigkeit, die Kontrolle der Selbstbewegung bei Blindheit nicht nur gewissermaßen von "außen", nämlich über die Feststellung von Defiziten visueller Leistungen zu analysieren, sondern einen "inneren" Zugang zu der spezifischen psychischen Organisation zu suchen über die Frage:

Welche Informationen können gegebene Wahrnehmungssysteme den durch die jeweiligen Aufgabenlösungen gestifteten Person-Umwelt-Beziehungen entnehmen?

Eine erste Annäherung an die Frage sei an einem einfachen Beispiel illustriert:

Ein blinder Rollschuh- oder Skateboardfahrer, der in einer hindernisfreien Sporthalle ohne didaktische Orientierungshilfen seine Runden dreht, benötigt Informationen über seinen Abstand zu der Wand, an der er entlangfährt, um diesen Abstand und seine Bewegungsrichtung zu regulieren, und über seine Annäherung an die Wand, auf die er zufährt, um seine Bewegungsrichtung rechtzeitig ändern zu können. Die Relation zum Untergrund ist hier zu vernachlässigen, da dieser waagerecht und plan ist. Neben haptischen (Fahrtwind, Abrollvibrationen, Zentripetalkräfte) und vestibulären Informationen (Kurveninnenlage, Zentrifugalkraft) ist der Akteur überwiegend auf akustische Informationen angewiesen. Die Abrollgeräusche erzeugen Resonanzen und Echos am Boden und an den Wänden. Deren Veränderungen informieren über Annäherungen und Distanzierungen. Handelt es sich um einen fortgeschrittenen Fahrer, dem der gegebene Bewegungsraum vertraut ist, so erlauben ihm Repräsentationen des Handlungsraums mit ihrer aktionsbezogenen Struktur und Metrik eine Abschätzung des Raumes und eine gewisse Antizipation seiner Umweltbeziehungen. Bekannt ist dieser Effekt als Raumgefühl. Die Konstanz und Regelmäßigkeit einer Sporthalle begünstigen die Ausbildung solcher Raumschemata.

Ganz anders stellt sich die räumliche Orientierung bei Sportarten im natürlichen Gelände dar. Beim alpinen Schifahren etwa ist die Fortbewegung auf verschiedene und sich permanent ändernde Umweltbedingungen abzustimmen, wie z.B. die Geländeneigung, Oberflächenstrukturen, Schneebeschaffenheit, die Position zum Hang und den Kurvenwinkel beim Schwingen usw. Gerade diese Veränderungen nun bieten Informationen im wesentlichen für die haptische Wahrnehmung. So sind beim Schwingen die Position zum Hang und die Geschwindigkeit über die sich im Schwungverlauf verändernden Kantendruckkräfte wahrzunehmen, und zumindest geübtere Fahrer nehmen Oberflächenstrukturen mit ihren Schischaufeln als verlängerten Füßen wahr.

Folgt man dem hier zugrundegelegten Analyseschema, indem man nach handlungsrelevanten Umgebungsmerkmalen, nach exekutiven und perzeptiven Aufgaben und nach benötigten und entstehenden Informationen fragt, wird deutlich, wieso für das einfache Geradeauslaufen auf einer Rasenfläche kaum handlungsrelevante Informationen zur Verfügung stehen und für den blinden Akteur gewissermaßen ein informationsarmer Raum entsteht.

Erkenntnisrelevante Analyseeinheit und theoretischer Bezug

Die Beispiele zeigen ebenso wie eine Reihe explorativer Experimente die folgenden, auch forschungsrelevanten Zusammenhänge:

1) Die Bedingungen der perzeptiven Kontrolle sportlicher Bewegungen bei Blindheit sind in hohem Maße von den Aufgabencharakteristika abhängig. Diese stiften je spezifische Person-Umwelt-Bezüge und bestimmen damit, welche Wahrnehmungssysteme welche Informationen darüber gewinnen können und welches Wahrnehmungssystem die Führungsrolle bei der räumlichen Orientierung übernimmt. Auf diesen Zusammenhang weisen auch Experimente mit Sehenden bei verschiedenen automatisierten Bewegungen hin, wo der Visusausschluß zu ganz unterschiedlichen Störungen der Bewegungsabläufe führte (vgl. auch Thomas, 1977).

2) Ein zweiter Bedingungsfaktor ist in den subjektseitigen Repräsentationen zu sehen. Dies entspricht wahrnehmungstheoretischen Ansätzen (z.B. Neisser, 1985; Prinz, 1983), die von einer Wechselbeziehung zwischen reizseitiger Information und subjektseitig gespeicherter Information ausgehen. Im gegebenen Zusammenhang sind zwei Repräsentationstypen zu unterscheiden: Dies sind zum einen gelernte Koordinationsmuster, die Informationen über räumliche und zeitliche Relationen liefern. Auf die grundlegende Bedeutung der aktionalen Komponente für die Raumwahrnehmung auch von Sehenden machen auch jene empirischen Befunde aufmerksam, die fanden, daß der phänomenale Raum nach Einheiten der Motorik strukturiert ist (z.B. Warren, 1984). Unter einem zweiten Repräsentationstyp ist symbolisch vermitteltes Wissen über räumliche Bezüge zu subsumieren, das beim Blinden aufgrund des eng begrenzten Wahrnehmungshorizonts Wahrnehmungsinformationen des Sehenden ersetzen muß. Erst durch

solche kognitiven Landkarten erhalten vollzugsemergente Wahrnehmungsinformationen ihre Verankerung.

3) Grundlegende Bedingung ihrer Möglichkeit überhaupt aber ist für die Raumwahrnehmung eines blinden Akteurs die Selbstbewegung. Hier liegt ein prinzipieller Unterschied zum Sehenden: Ist der Sehende zur vorausschauenden, aktionsbezogenen Abschätzung und Strukturierung des Raumes und damit zur wahrnehmungsgestützten Antizipation von Person-Umwelt-Bezügen ohne Selbstbewegung in der Lage, so erfährt der Blinde wahrnehmungsgemäß in der Regel erst etwas über den Handlungsraum, wenn er sich bewegt. Am Beispiel des blinden Akteurs wird die unteilbare Einheit von Bewegen und Wahrnehmen und die reziproke Beziehung zwischen beiden evident. Denn die Information für die Wahrnehmung entsteht nur *durch* die Bewegung und ist zugleich Voraussetzung *für* die zielgerichtete Bewegung, ein Bedingungsverhältnis, das v. Weizsäcker (1968) in das Modell des Gestaltkreises faßte.

Ein wesentlicher Teil der Information für die Kontrolle der Fortbewegung erwächst somit aus dem Handeln selbst und ihr Wesen liegt in der fortwährenden Veränderung der Person-Umwelt-Beziehung. Nur den Veränderungen im Fluß proximaler Reize kann die Wahrnehmung Informationen in Form struktureller Invarianten entnehmen. Es sind, wie Munz (1989, S. 66) es ausdrückte, "Nichtveränderungen in Veränderungen", die informativ sind.

Im Lichte dieses Ansatzes wird deutlich, daß die Wahrnehmungssysteme blinder Sportakteure viele Informationen liefern können, die auch das visuelle System liefert, daß aber durch die unmittelbare Bindung der Wahrnehmung an die Selbstbewegung diese gewissermaßen immer am Ort des Geschehens ist. Der blinde Sportler bewegt sich daher immer auch ein Stück weit in den vorgestellten Raum hinein.

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Das Mass und die Konstanz raum-zeitlich relationaler Strukturen in der Ideomotorik bei Rennschlittensportlern

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Theoretische Grundlagen

Seit der Ausformung der Theorie Generalisierter Programme von Schmidt (1975) ist der Problemkreis des Maß' und der relativen Konstanz relationaler Strukturen bei Raum-Zeit- und Kraftmustern von Bewegungen als Invariante bei den verschiedenen Aufgabenklassen noch mit Klärungsbedarf zu betrachten (Roth, 1987). Die Invarianten sind die entscheidenden Größen im gesamten psychomotorischen Prozeß. Sie müssen sowohl in der Wahrnehmung, im subjektiven Abbildprozeß bis hin zur Motorik (Pöhlmann, 1986) primär eine bewegungsregulierende Funktion haben.

Im Leistungssport gilt es, ein hohes Niveau und die Konstanz sportlicher Leistungen zu erreichen. Dies geschieht durch die Sicherung einer dynamisch-relationalen Invariante der Bewegungsregulation, vor allem auch bei Beeinflußungen und Abweichungen in bestimmten Maßzonen (Pöhlmann, 1986).

Von Interesse sind dabei die Maßzonen der psychomotorischen Invarianten:

a) in denen bei metrischer Variation/Parametertransfer die Invarianten stabil bleiben oder "zerbrechen" und eine neue Technikstruktur genutzt wird;

b) in denen bei qualitativ-topologischer Variation/Programminterferenz die relationalen Strukturen des Sportlers störresistent sind.

Sportpraktische Grundpositionen

Da der Extensivierung des Trainings im Leistungssport Grenzen gesetzt sind, wird die Trainingsintensivierung zunehmend zu einem entscheidenden Faktor der Leistungsentwicklung (vgl. Frester, 1974).

Das erfordert besonders im Rennschlittensport neben dem konkret realen Training die Anwendung ideeller Trainingsmethoden sowie die verstärkte Nutzung der Gesetzmäßigkeiten des motorischen Lernens.

Die Vermeidung von Interferenzen und das Sichern von Transfereffekten lassen motorischen Lernfortschritt erwarten (Leist, 1978). Für den Bereich der Ideomotorik automatisierter/stabiler Bewegungsvollzüge sind die Übertragungsphänomene noch wenig experimentell gestützt und deshalb für den Praktiker nicht klar zu handhaben.

Aus leistungssportlichen Untersuchungen von Beier (1978) ging hervor, daß die Stabilität der Vorstellungszeit als Ausdruck der Qualität der Bewegungsvorstellung angesehen werden kann. Aus Studien von Gutewort und Loosch (1982) sind ideomotorische Reproduktionszeitverlängerungen und aus Studien von Pöhlmann (1982) ideomotorische Zeitverkürzungen bekannt. Die Ursachen solcher Veränderungen sind bekannt, die strukturellen und zeitlichen Transferwirkungen auf die Qualität der Bewegungsvorstellung jedoch weitgehend unerforscht.

Aus diesen Überlegungen heraus sind folgende Problemkreise zu klären:

a) Existieren individuelle Invarianten bei Bewegungsvorstellungen, bei denen eine Zeitverlängerung möglich ist? Wie groß ist dabei die Maßzone der Verlängerung?

b) Wie stark kann man die Invarianten zeitlich verkürzen, ohne das relationale Zeitmuster zu zerstören? Gibt es Transfereffekte auf die "normale" Zeit der Bewegungsvorstellung?

c) Wie groß ist die individuelle Störresistenz/Belastungsverträglichkeit der Ideomotorik eines Sportlers?

Methode

Der Ideomotorische Steuertest -IST- (Pöhlmann & Fackelmayer, 1975) stellt ein diagnostisches Verfahren zur Überprüfung von Schwerpunkten des ideomotorisch-operativen Abbildes der verinnerlichten Steuerlogik und der Reproduktionsgüte der sportlichen Handlung dar (Wolf, 1989).

Im gerätetechnischen Aufbau sind ein standardisierter Meßschlitten mit Gebern in Form von Halbleiterdehnmeßstreifen zur elektrischen Messung von mechanischen Größen (Kräften) angebracht.

Der Sportler liegt während des Tests in Fahrlage auf dem Testschlitten und erhält die Aufgabe, seine beste Realfahrt auf einer Rennschlittenbahn zu simulieren.

Die Sportler rodeln vom entsprechenden Start ihrer Wettkampfstrecke und markieren mit Hilfe eines Zeittasters Start, Kurveneinfahrt, Kurvenausfahrt und Zieleinfahrt.

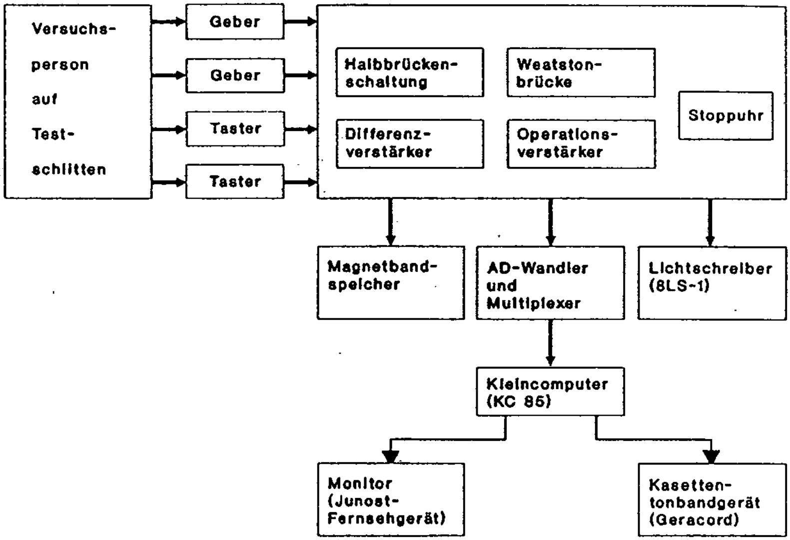

Abbildung 1. Geräteaufbau des IST - Meßplatzes.

Es wurde folgendes Versuchsprogramm entwickelt:

1. Ideofahrt Oberhof (Erwärmung)
2. Ideofahrt Oberhof
3. Ideofahrt Oberhof
4. um 50 % zeitlich gestauchte Ideofahrt Oberhof
5. um 100 % zeitlich gedehnte Ideofahrt Oberhof
6. Ideofahrt Oberhof
7. Ideofahrt Oberhof
8. um 100 % zeitlich gedehnte Ideofahrt Oberhof
9. um 50 % zeitlich gestauchte Ideofahrt Oberhof
10. Ideofahrt Oberhof
11. Ideofahrt Oberhof
12. Ideofahrt Altenberg
13. Ideofahrt Oberhof

Im Versuch wurden pro Fahrt neben der Ideogesamtzeit an 29 Stellen (Herren) und 22 Stellen (Frauen) jeweils Zeit- und Kraftmeßwerte (getrennt für beide Beine) gewonnen.

Das Versuchsprogramm wurde von 21 Sportlern des B-Nationalmannschaftskaders der DDR in der Saison 1989/1990 durchgeführt.

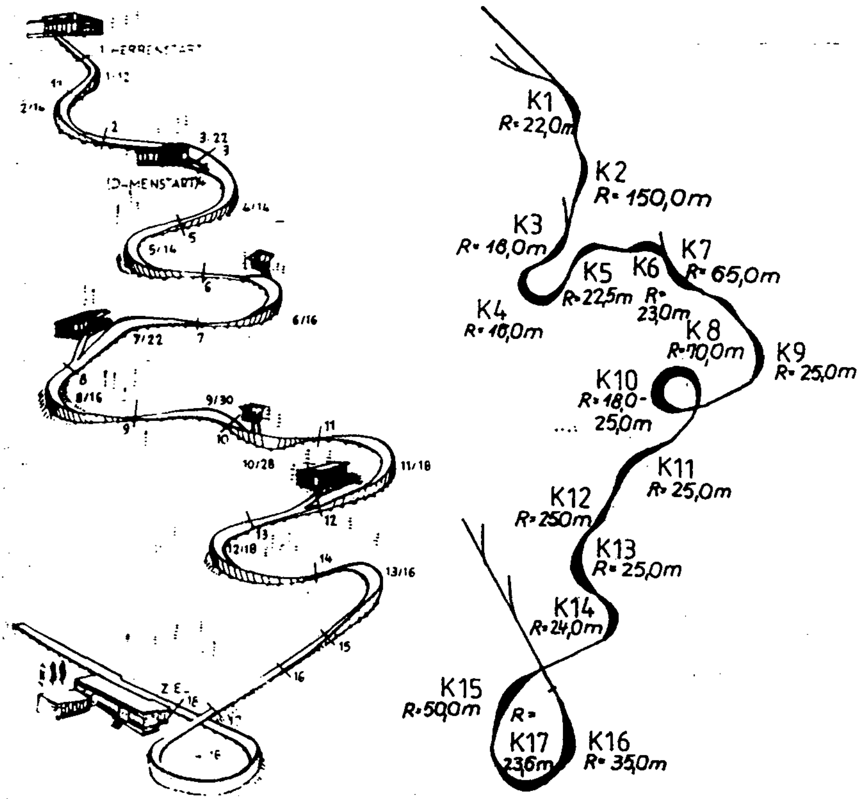

Abbildung 2. Geometrisches Anforderungsprofil zweier Bahnen (Oberhof-links; Altenberg-rechts).

Ergebnisse und Interpretation

Einige erste ausgewählte Ergebnisse sprechen:

- für eine lernniveauabhängige und aufgabenspezifische Stabilität und Störresistenz individueller Invarianzen,

- für eine individuelle Breite der Maßzonen bzw. Stauch- und Dehnbarkeit invarianter Strukturen.

Alle Sportler (N=26) sind als Fortgeschrittene im ideomotorischen Lernprozeß ihrer Sportart zu bezeichnen. Die Gesamtideofahrzeiten der "Normalfahrten" Oberhof sind zeitlich relativ stabil (Standardabweichungen). Ein Parametertransfer beeinflußt die individuell relationale Struktur nicht bedeutsam. Die Gesamtideozeiten stabilisieren sich von Fahrt 1 zu 3, über 6, 7 und 10, 11 bis Fahrt 13 ungeachtet aller zeitlichen Störeffekte der Fahrten 4, 5, 8, 9, 12 (Tabelle 1). In den ungeübten, weniger stabilen (Standardabweichung) Ideofahrten (Verlängerung/Verkürzung) treten zeitliche Interferenzeffekte folgender Art auf:

- eine zeitlich verlängerte Ideofahrt (Fahrt 4) verkürzt eine zeitlich zu verlängernde Fahrt (Fahrt 5)
- eine zeitlich gedehnte Ideofahrt (Fahrt 8) verlängert eine zeitlich zu verkürzende Ideofahrt (Fahrt 9).

Übertragungseffekte bei Programminterferenz als topologisch-qualitativ verschiedene Bahnanforderungen konnten auch unter Belastung (13 Ideofahrten) und vorherigen Parameterstörungen nicht signifikant nachgewiesen werden.

Tabelle 1. Ideo-Gesamtzeiten.

Ideofahrtnr./ Kürzel im Progr.	Mittelwert der Ideogesamtzeit	Standard-abweichung
1 /Erwärmung	46.66 s	5.65
2 /Normal	47.04 s	4.46
3 /Normal	46.84 s	3.61
4 /Verkürzt	29.31 s	4.52
5 /Verlängert	64.65 s	9.06
6 /Normal	45.70 s	4.73
7 /Normal	47.47 s	3.86
8 /Verlängert	77.20 s	7.50
9 /Verkürzt	31.99 s	4.18
10 /Normal	46.08 s	3.54
11 /Normal	46.46 s	3.84
12 /Altenberg	60.76 s	5.02
13 /Normal	44.94 s	2.98

Die mit dem IST-Verfahren ermittelten Werte wurden entsprechend dem Verrechnungsprinzip in individuelle Ideozeitquotienten transformiert.

Die mit Hilfe einer eindimensionalen Varianzanalyse ermittelten F-Werte (F-Probability) differieren exemplarisch für eine Versuchsperson zwischen:

$$\text{F-Prob-Werte} = 0.4083 < x > 0.4451$$

und verdeutlichen für die obige Versuchsperson die Gleichheit ihrer relationalen Strukturen in den Maßzonen. Die "normale" und "verkürzte" Struktur der Oberhofer Rennschlittenbahn des Sportlers sind in den Abbildungen 3 und 4 dargestellt.

Die von Schmidt (1975), Pöhlmann (1986), Roth (1987) u.a. bestimmten Invarianten: relatives timing, sequencing, relative Krafteinsätze sind abhängig von der Art der motorischen Anforderung in bestimmten und noch zu bestimmenden Grenzen oder Maßzonen echt invariant und werden durch variable Programmbestandteile so ergänzt, daß die Bewegung anforderungsgerecht reguliert werden kann. Die relationale invariante Struktur "relatives timing" dieses Sportlers ist in einer Maßzone von 150% stabil und reagiert nicht mit Strukturwechsel.

Eine Kovariation der Invariante "relatives timing" mit der Invariante "relativer Krafteinsatz" in der relationalen Struktur des Sportlers wird in einem nächsten Schritt zu prüfen sein.

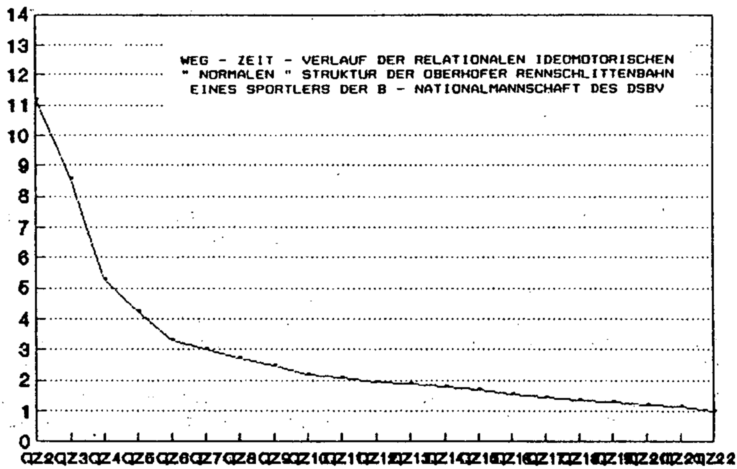

Abbildung 3. Weg-Zeit-Verlauf der relationalen ideomotorischen "normalen" Struktur der Oberhofer Rennschlittenbahn eines Sportlers der B-Nationalmannschaft des DSBV.

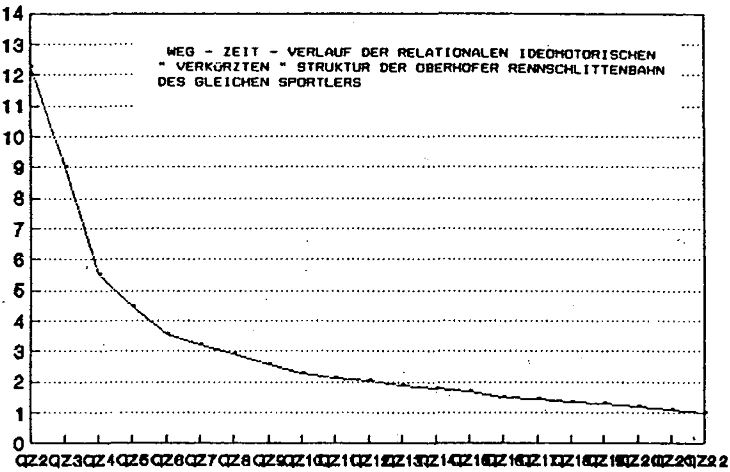

Abbildung 4. Weg-Zeit-Verlauf der relationalen ideomotorisch "verkürzten" Struktur der Oberhofer Rennschlittenbahn des gleichen Sportler.

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SPATIAL PREDICTIONS IN CATCHING UNDER MONOCULAR CONDITIONS

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Introduction: An Ecological Perspective on Catching

An ecological perspective on the control of catching assigns primary importance to the fact that, for successful catching of a ball, all the necessary information on which the spatial positioning and timing of the grasp of the hand is made is available in the optic array (Savelsbergh, 1991) The catcher must have access to predictive temporal and spatial information. What are the potential sources?

Monocular Predictive Temporal Source

The approach of a ball can be considered to give rise to an expanding optical array. It was Lee (1976, 1980), who demonstrated that the pattern of optical expansion, brought about by the relative approach between the actor and the environmental structure of interest, contained predictive temporal information. This information, the inverse of the relative rate of dilation of the closed optical contour of a surface generated in the optic array, specifies a first order temporal relation between actor and environment, namely the remaining time-to-contact if the speed of relative approach were to remain constant (the optical variable Tau). Evidence for the primacy of Tau in catching was provided by Savelsbergh and Whiting (Savelsbergh, Whiting & Bootsma, 1991; Savelsbergh, Whiting, Pijpers & Van Santvoord, submitted) in a series of experiments which required subjects to catch a luminous ball attached to a pendulum apparatus (no spatial uncertainty) in a totally dark room. Three ball sizes were used, randomized over trials. Two of these were 5.5 cm and 7.5 cm in diameter. A third ball could be made to change its diameter during flight from 7.5 cm to 5.5 cm. By using this third deflating ball, the provision of non-veridical information — in the sense that the time-to-contact of the approaching ball is not consistent with the rate of optical dilation — was achieved. The results showed that the time of appearance of the maximal opening and closing velocity of the fingers was significantly *later* for the deflating ball than for the balls of constant size as a result of an underestimation of time-to-contact under monocular as well binocular vision conditions. The subtlety of the tuning demonstrated in these experiments points not only to a closely coupled perception-action system, but also to the importance of the optical variable Tau for the control and coordination of the timing of the grasp action (for evidence at a muscular level see Savelsbergh, Whiting, Burden & Bartlett, in press). So much for the source of timing information. What about precision which is also a prerequisite? Has an ecological approach anything to contribute in this respect?

Monocular Predictive Spatial Information Source

A source of spatial information, based on the monitoring of optical expansion and displacement, has been put forward by Todd (1981). In a series of computer simulation experiments, Todd demonstrated that subjects can accurately predict whether an approaching object, following a parabolic flight path, will land in front or behind them, even when only part of the trajectory is visually available. Todd demonstrated that such information is specified, directly, by the ratio of two time-to-contact (Tau) components, viz. time-to-contact with the vertical plane through the point of observation and time-to-contact with the horizontal plane through the point of observation. The following predictions can be made:

When Tau vertical/Tau horizontal$=1$, then the ball will land at the point of observation, when Tau vertical/Tau horizontal>1, then the ball will land behind the point of observation and when Tau vertical/Tau horizontal<1, then the ball will land in front of the point of observation.

As Todd used computer simulations, binocular cues were not available, i.e., the 'Todd ratio' can be obtained *monocularly*. However, the work of McLeod, McLaughlin and Nimmo-Smith (1986), utilising a ball-striking task, showed the superiority of binocular vision in making spatial predictions. This discrepancy in the literature findings was the motivation for the experiments to be reported.

Experiment 1: Catching Under Monocular and Binocular Conditions

In order to answer the question whether catching behaviour is superior under binocular rather than monocular vision conditions, subjects were required to catch while the left, right or both eyes were open (Savelsbergh & Whiting, 1992). The dependent variables were: number of catch errors (i.e., number of balls not caught); number of spatial errors (a failure to make contact with the ball in the region of the head of the metacarpals) and number of temporal errors (the ball makes contact with metacarpal regions but grasp is too early or too late). The results are graphed in Figure 1.

With respect to the dependent variables catch and spatial errors, significantly more errors were made under the monocular condition in comparison to the binocular condition. For the temporal errors no significant effect of vision was found, indicating that the performance under the monocular vision condition reached similar performance levels to those under the binocular vision. The latter finding is in agreement with the use of Tau information in order to judge time-to-contact. The finding of more spatial errors under the monocular condition in comparison to the binocular, is in agreement with the results of McLeod et al. (1986). However, the performance under the monocular condition is fairly high. Therefore, the superiority of the binocular condition might be attributed to the fact that subjects have more experiences under binocular viewing condition. The second experiment will explore this contention.

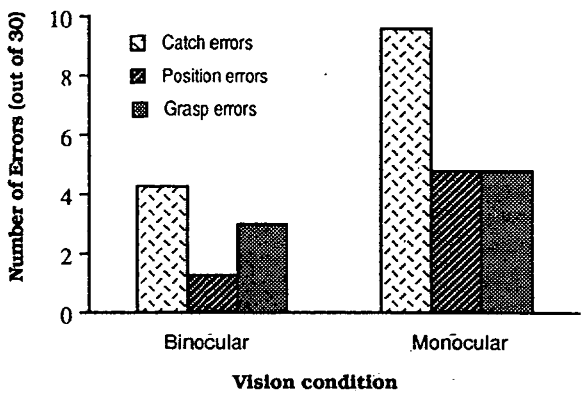

Figure 1. The catch, spatial and grasp errors under both vision condition.

Experiment 2: The Acquisition of Catching Under Monocular Conditions

In order to remove the possibility of the use of environmental spatial information sources (e.g. background texture) subjects were required to perform and train — monocularly or binocularly — with only a luminous ball, delivered by a ball-projection machine with a speed of 10 m/s, available in an otherwise totally dark room.

Two groups of 5 subjects of equal catching ability received training for five consecutive days, two training sessions each day (one in the morning and one in the evening). A training session consisted of three blocks of thirty trials with a rest period of two minutes between each block. One group received training for five sessions under the binocular condition and switched over on day 3 to training under the monocular condition (so-called BiMo group). The second group training conditions were counterbalanced (so-called MoBi group).

It has to be appreciated that where one source of spatial information is nested within another (in the sense, for example, that the binocular condition does not deny the use of monocular information whereas the monocular condition, by definition, denies the use of binocular information) transfer of training effects might be expected. For example, if subjects make use (only) of optical comparity spatial information under binocular conditions there should be a decrement in performance when, subsequently, they are required to perform under monocular conditions although improvement might be expected if they continued to have experience under the latter condition and, hence, became sensitized to that type of information. If, however, subjects — under binocular conditions — are making use of optical expansion information for making spatial judgements in the manner discussed by Todd (1981) for example, the requirement, subsequently to perform under monocular viewing conditions should not produce negative transfer effects.

Dependent variables: the number of balls caught out of 90; the number of complete misses out of 90 trials (a failure to make any contact with the ball).

The results for both dependent variables for the first five training session are graphed in Figure 2, while the findings with respect to the transfer on day 3 are graphed in Figure 3.

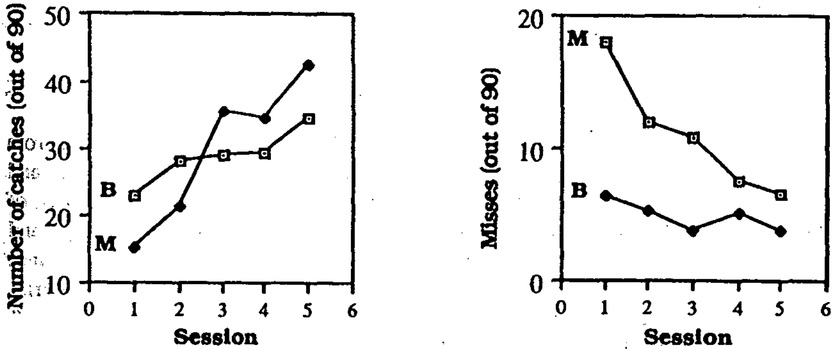

Figure 2. The training results for the first five sessions for both groups (M=monocular, B=binocular).

As Figure 2 shows, subjects under both monocular and binocular training conditions significantly improved their performance as indexed by number of catches. The monocular training group also showed a significant reduction in spatial errors (as indexed by number of complete misses) over training sessions, i.e., they learned to be more spatially accurate in the positioning of the catching hand.

Transferring, as Figure 3 shows, from performing under the binocular condition to performing under the monocular condition (BiMo-group) resulted in significantly more spatial errors being made whereas transferring from monocular to binocular (MoBi-group) had no significant effect on spatial errors.

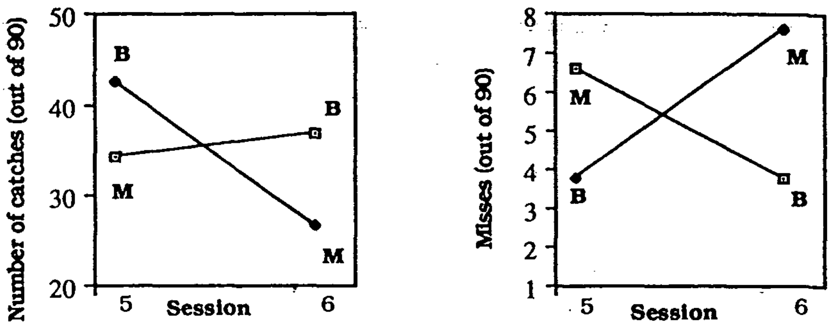

Figure 3. Transfer results (session 5 to 6); the BiMo group transfered from binocular (B) to monocular (M) and the MoBi group transfered from monocular (M) to binocular (B).

Conclusions

The findings of both experiments demonstrate that spatial information derived from the Todd-ratio can, in principle, be used by catchers in order to position the hand accuratly in the flight-path of the ball. The fact that the Todd-ratio is composed of Tau-variables, implies that this spatial information source is *directly* and *monocularly* available in the optic array. This does not mean that catcher cannot make use of other spatial information sources, e.g., optical comparity or disparity (see Bevelery & Regan, 1973; Savelsbergh & Whiting, 1992). In fact, Figure 3 shows that when transfered from binocular to monocular a decrement in performance is found, which suggests that another (binocular) spatial source may be used under the binocular condition in order to position the catcher's hand. Together, these two experiments hint at the use by subjects of multi-sources of information, i.e., subjects are able to exploit whatever information is available. Experience may lead to subjects becoming sensitive to particular kinds of information, i.e., that provided by monocular viewing (Savelsbergh & Whiting, 1992).

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INTERLIMB INTERFERENCE IN SIMPLE RATIOS

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Introduction

The current study gives the chance to study the bimanual coordination in lab situation, fact that might be applicable to sport and dance situations. For example the "butterfly" swimming stroke can show us how difficult people find it to follow the right rhythm. Ideally the legs stroke and the arms stroke are in a 2:1 ratio, but there is often the tendency for the arms to follow the movement of the legs in a 1:1 ratio. The literature refering to human coordination suggests a simple timing model where the nervous system easily divides the temporal sequences into parts of equal length according to the accentuate events, called beats (beat-based model, Povel, 1981; cf. Figure 1).

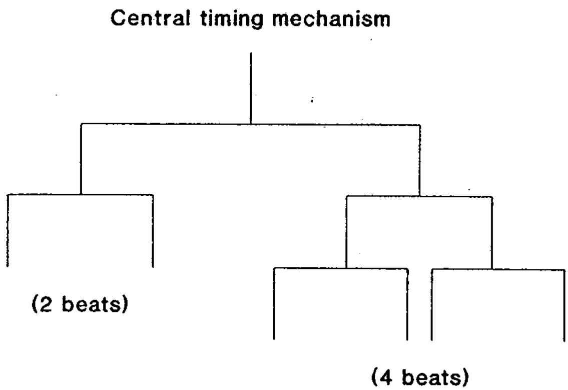

Figure 1. Simple timing model (adapted by Povel, 1981).

Duncam (1979) examined a finger tapping task and he observed a tendency for each hand to perform the task assigned for the other hand. Klapp (1979) found that performance in a periodically repeating keypress was degraded when the tasks required by the two hands were not harmonic, but it was not degraded when the two tasks had a harmonic related period.

This was also suggested by Deutsch (1983) who concluded that the harmonic timing relationship, that is inter ratios of 2:1 and 3:1, are easily to perform while nonharmonic ratios of 3:2 or 5:4 are causing interference. The discrete reversal points on fingertapping tasks are used as dependent measure in the studies. However, as previously referred to in the "butterfly" stroke, there are sport movements in 2:1 simple ratio that cause interference between the limbs. Kelso, Holt, Robin and Kugler (1981) observed interlimb interference in harmonic tasks. MacNeilage (1989) found that bilateral movements requiring similar spatiotemporal patterns are easy to be performed. On the other hand, tasks that require different spatiotemporal patterns seem to be difficult to be performed.

When we focus on the spatial pattern of the movement rather than on the timing of the reversal we may see interference between the two limbs even for harmonic ratios. That is exactly what the current study is examining.

Method

20 subjects participated in the study, the data of 18 of them were analysed. The task required simultaneous bilateral arm movements. The nondominant arm in the frequencies of 2.0 Hz (1:1 ratio), 1.0 Hz (2:1 ratio) and .67 Hz (3:1 ratio). 15 total trials were produced, 5 trials for each of 3 conditions (cf. Table 1).

	Nondominant Arm	Dominat Arm		
Single	2.0 Hz	.67 Hz	1.0 Hz	2.0 Hz
Paired	2.0 Hz	.67 Hz	1.0 Hz	2.0 Hz

Table 1. Experimental design.

The 1:1 ratio was always presented first while the 2:1 and 3:1 were counterbalanced among the subjects. Each trial lasted 5 sec. The time period, the amplitude, the velocity and the percentage portion of the trajectory were examined to see if there was any interference between the arms. The differences between the alone (ideal) and the paired (experimental) conditions for all the variables indicated substantial interference between the limbs.

Results

Results were analysed qualitatively and quantitatively. Figure 2A contains an example of relatively successful paired small inconsistancies in the trajectory. Figure 2B represents a variation of the "waiting" strategy, the most typical kind of interference that was observed, where the dominant arm was pausing while the nondominant was moving. A different category shows a slow flexion of the dominant arm compensated for the extra correspondent cycle movements of the nondominant. This was followed by a symmetrical fast extension of both arms (Figure 3).

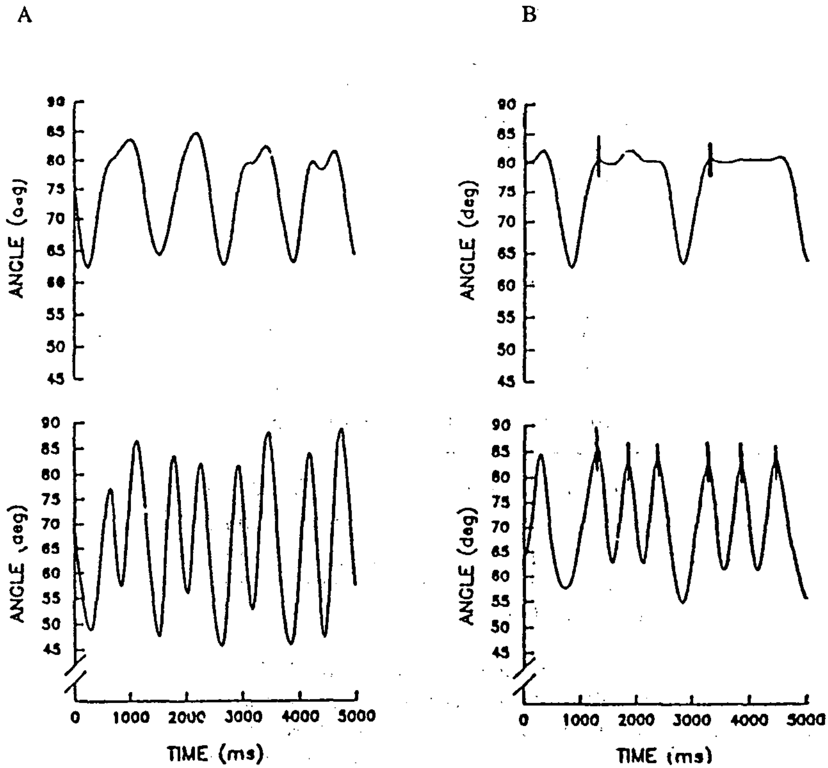

Figure 2. Relatively successful paired trials (A). A typical kind of interference: The "waiting strategy" (B).

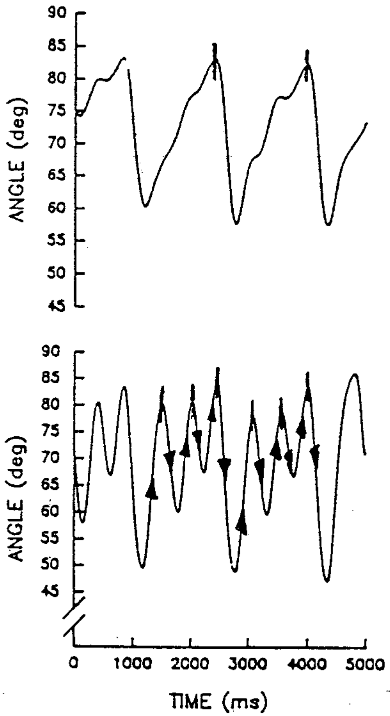

Figure 3. Slow flexion of the dominant arm, fast extension of both arms.

In the "overflow" case the interference is detectable in the nondominant arm as overshooting in the extension phase (Figure 4A). The general coupling of both arms indicated the difficulty of both arms to differenciate their movements (Figure 4B).

Quantitative results (repeated measures 2x2 ANOVA) indicated that the arms displayed interference when they were paired. Analytically, the results for each one of the variables are as follows:

The time period spent between each two flexion peaks for each of the three frequencies was longer in the paired than in the alone conditions; that indicates temporal interference.

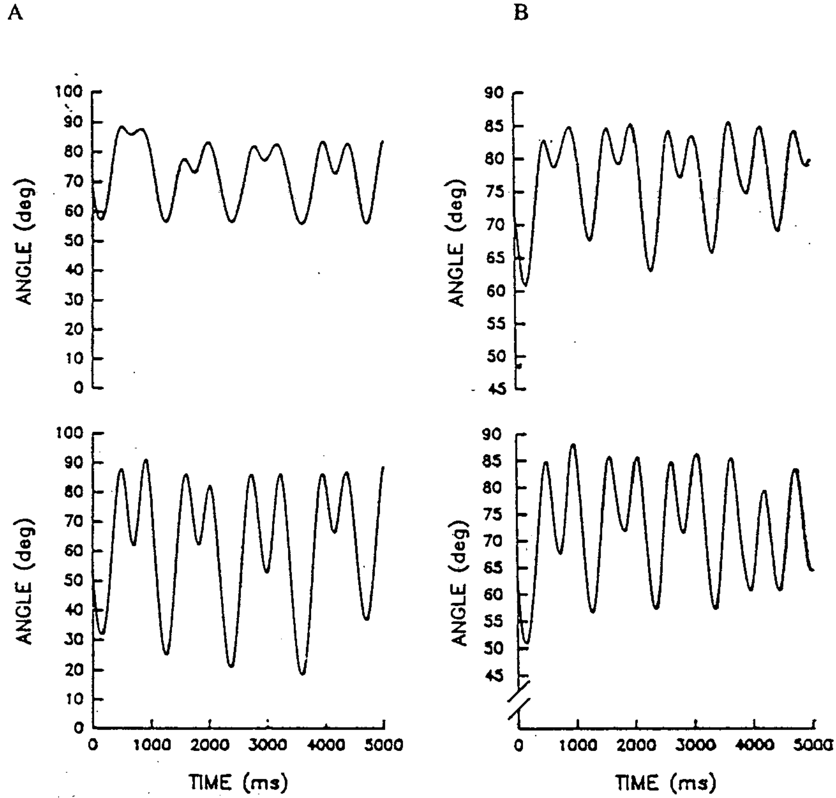

Figure 4. Overflow case of interference (A). General coupling of both arms (B).

Amplitude was determined as the difference between the peak flexion angle and the peak extension angle. The paired conditions had larger amplitudes than the alone (Figure 5). The nondominant arm had the larger amplitude in the 2:1 ratio. The dominant arm increased the amplitude in the 1:1 ratio and in the 3:1 while it decreased in the 2:1. One possible explanation why the 1:1 ratio appeared to have interference is due to the superimposition which means that while the pattern was the same for both limbs, the effect of the one was added to the other in a form of overflow. Amplitude indicated spatial interference.

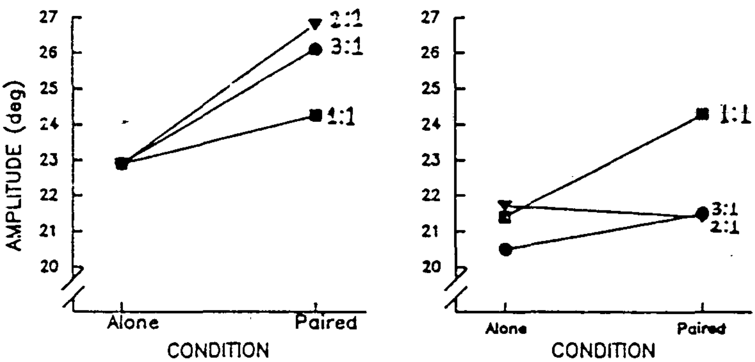

Figure 5. The amplitude for alone and paired conditions for the nondominant arm on the left side of the figure and for the dominant arm on the right side of the figure.

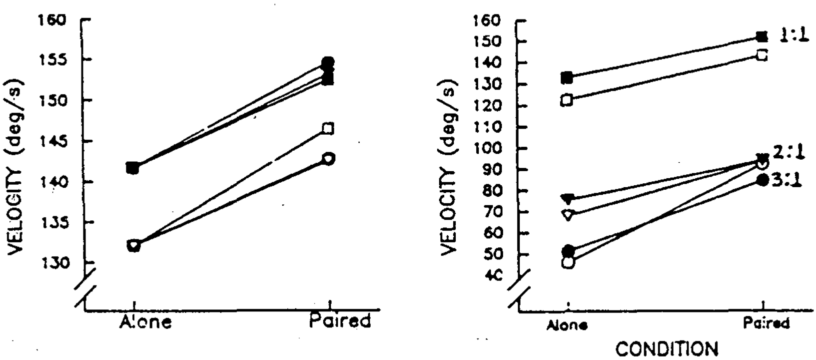

Figure 6. Flexion and extension velocity for the dominat arm.

Flexion velocity and extension velocity showed how fast or how slow the arms were moving when they have to execute the task in alone or in the paired conditions (Figure 6). It was generally observed that flexion velocity was greater than extension velocity, a fact that shows that the arms were moving faster towards the body midline (70 deg. flexion). For the D arm results showed a progressively larger difference between the alone and paired velocity as the ratio increased from 1:1 to 3:1. The percentage increase from alone to paired conditions was as follows:

for the 1:1 ratio 15.5%, for the 2:1 ratio was 31.5% and for the 3:1 82,5%.

That was indicative for the greater interference that appeared in the 3:1 ratio. Concluding we can say that velocity served as a variable showing spatiotemporal interference.

The trajectory continuity was the last and perhaps the most representative measure showing interlimb interference.

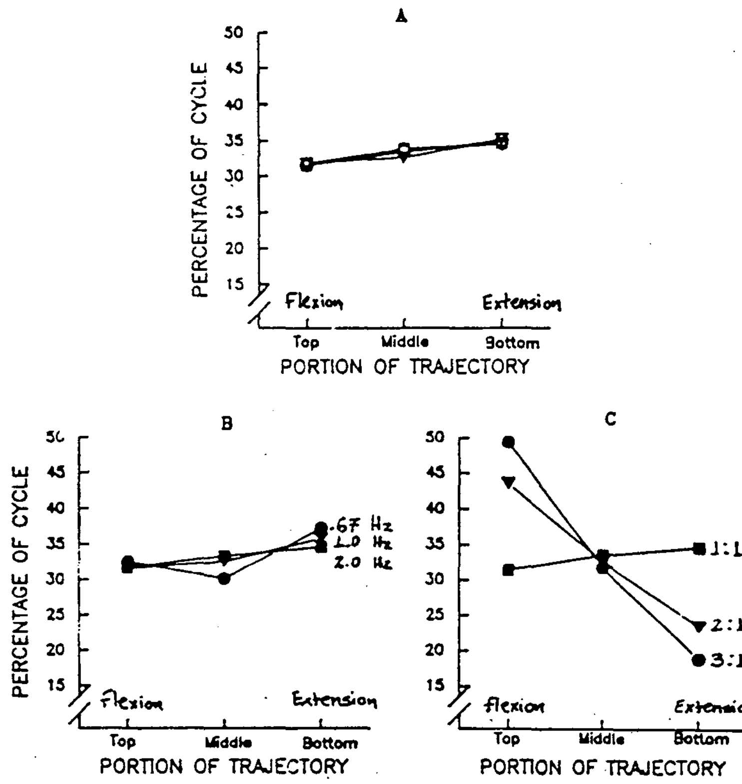

Figure 7. The percentage of time spent in each one of the three locations of movement cycle for the nondominant arm in alone trials (A). The percentage for the dominant arm in alone trials (B). The percentage for the dominant arm in paired trials.

It represents the percentage of time spent in each one of the three locations (top, middle, bottom) of the movement cycle. For a true sinusoidal oscillation each one of these portions should take 33% of the movement cycle. For the ND arm (Figure 7A) the proportions remained fairly equal among single and paired conditions. For the D arm (Figure 7B) in single conditions the percentages remained fairly equal even if there was a slight tendency to spend more time in the extension part.

In Figure 7C we can see the interesting different slopes that appeared for each of the 3 ratios in the paired conditions.In the 1:1 ratio the percentages remained the same through the 3 locations showing no interference between the limbs when they moved in the same frequency. In the 2:1 ratio, there was an evident tendency of the D arm to spend more time on the flexion part and less time on the extension part of the movement than on the middle of the trajectory. In the 3:1 ratio the tendency to spend more time in flexion and less time in extension was even greater than in the 2:1 condition. This indicates interference between the limbs with the D arm apparently waiting until the ND finished the correspondent 2 or 3 cycle movements. Trajectory continuity showed spatial interference.

Conclusions

Since only harmonic timing ratios were used but interference was evident between the limbs, we can conclude that the current study provides evidence against the simple timing model which suggests that the system easily divides the temporal sequences into equal parts.

The second point that can be concluded is that the spatial pattern seems to be the reason of the interference because there was a changing relative phase throughout the experiment.

Applying these finding to sport situations, we can give a reason why movements in 2:1 ratio, as the "butterfly" stroke, seem to be difficult to perform; because the relative phase between the arms and the legs is different.

Considering other athletic application we can refer to dancers when they have to perform different spatiotemporal movements at the same time with different limbs (Hammond, 1984). A frequent example is the simultaneous circle arm movement in front of the head while the legs are moving in different direction. We can also refer to the basketball playmakers when they are dribbling the ball with one arm and at the same time they are showing the game system to the other players with the other arm.

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Antizipation und Reaktion bei Handlungen unter Zeitdruck in den Sportspielen

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Deutschland

Problemstellung

Bei Sportspielen (Rückschlagspielen) mit hohen Ballgeschwindigkeiten (z.B. Tennis) steht der Gegenspieler unter großem Zeitdruck. Dies trifft in besonderem Maße für den Returnspieler zu. In diesem Zusammenhang stellt sich immer wieder die Frage, ob die zur Verfügung stehende Zeit tatsächlich so kurz ist, daß der Spieler "antizipieren" muß, um überhaupt erfolgreich agieren zu können. Aus der Vielfalt der Begriffsbestimmungen (s. Döbler, Schnabel & Thiess, 1988) wird das in Tabelle 1 beschriebene Verständnis der Antizipation zugrundegelegt:

Tabelle 1. Formen der Antizipation im Tennis.

Antizipation	
Erfahrungsantizipation	**Wahrnehmungsantizipation**
Aufschlagsart und -richtung antizipieren: a) taktische Antizipation b) aus Position, Schlägerhaltung Aushol- und Schlagbewegung des Aufschlägers vor dem Balltreffen	Treffort und -zeitpunkt aufgrund der Wahrnehmung des Ballflugs antizipieren

Im vorliegenden Beitrag wird v.a. die "Erfahrungsantizipation" untersucht, wobei die Frage, ob der Rückschläger vor dem Treffpunkt des Aufschlägers die Ausholbewegung einleitet, besondere Berücksichtigung findet. Bisher wird der Antizipation — im Sinne einer frühzeitigen Vorwegnahme gegnerischer Handlungen — ein sehr hoher Stellenwert beigemessen (vgl. z.B. Ritzdorf, 1982; Neumaier, 1984, 1985). Die Bedeutung der Reaktion tritt dabei eher in den Hintergrund und wird häufig als abhängig vom Antizipationsvermögen betrachtet. Zur Überprüfung dieser weitläufigen Einschätzung ist das Returnverhalten von Tennisspielern unterschiedlicher Leistungsstärken (Weltklasse-, Oberliga- und Freizeitspieler) mit Hilfe einer High Speed Videokamera (200-400 Bilder/s) untersucht worden. Analysiert worden ist der zeitliche Ablauf von tennisspezifischer Bein- und Schlagarbeit. Zu diesem Zweck ist die Ausführung des Returns in einzelne Bestandteile der Haupt- und Nebenaktionen gegliedert worden. Zu diesen Zeitmerkmalen zählen u.a. die Differenzen vom "Treffpunkt des Aufschlägers" bis zur "Einleitung der Ausholbewegung", bis zum "Beginn der Umkehrphase (Anfang Schlägervorschwung)" bis zum "Treffpunkt des Returnspielers".

Zeit- und Geschwindigkeitsmessungen im Sportspiel Tennis

Ausgangspunkt für die oben genannte Fragestellung sind Zeit- und Geschwindigkeitsmessungen des 1./2. Aufschlags bei Spielern nationaler und internationaler Spitzenklasse. Dabei sind einerseits die Ballabfluggeschwindigkeiten auf den ersten 2-3m gemessen, andererseits die Zeiträume und Geschwindigkeiten auf definierten Teilstrecken ermittelt worden (Treffpunkt Aufschläger - Bodenkontakt Aufschlagfeld - Treffpunkt Returnspieler). Die Messung der Anfangsgeschwindigkeiten und die Ermittlung der Zeiten für die Teilstrecken beim Aufschlag erfolgte mit einem High Speed Video bei 400 bzw. 200 Bildern/s. Die Messung der Anfangsgeschwindigkeiten ergibt für aufschlagstarke Spieler (J. Hlasek, M. Rosset, M. Stich) Werte von über 200km/h beim 1. und etwa 140km/h beim 2. Aufschlag (Abbildung 1).

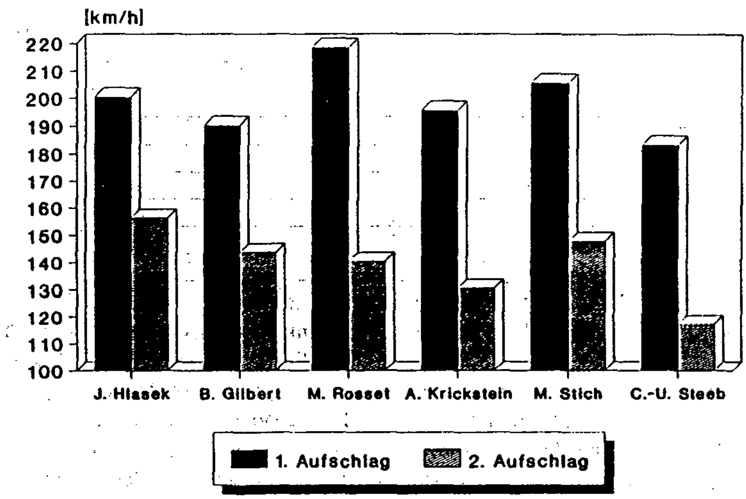

Abbildung 1. Geschwindigkeitsmessung 1./2. Aufschlag: Weltklassespieler.