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APPLICATIONS OF SYSTEMS DYNAMIC PRINCIPLES TO TECHNIQUE AND STRENGTH TRAINING

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Introduction

Highly skilled levels in sports are often associated with an enormous amount of coordinative and strength training. Large numbers of repetitions are often considered a necessity to achieve mastery, and frequentlythese repetitions are related to the same movement. Based on the philosophy of linear causality it is assumed that an athletes‘ movement will improve towards championship by copying the „ideal“ movements as often as possible. Therefore, general „soll-values“ (to be achieved) are derived from „ideal“ movements, typically defined by means of world class athletes. However, a change in the understanding of causality and problems with the generality of this approach in most recent research lead to rethink the traditional training philosophy.

At first glance the concept of ideal movements seems quite plausible. Investigating ideal movements in more detail, two main problems emerge. First, it seems difficult to coincide the philosophy of generality with recent investigations where the individuality of every persons‘ movement could be shown quantitatively. The second problem is related to the stability of movements and its relationship to an ideal movement. When repeated movements are investigated in more detail and compared with each other, it can be stated that the movements always show fluctuations and it seems almost impossible to produce the same movement twice ([3-5]. This leads to problems with the idea of an ideal movement and to the general question „When the next movement is different from the last anyway, what can be the ideal movement?“

Suggestions for the solutions of these problems can be derived from the systems dynamic approach. A brief introduction into systems dynamic approach and possible practical consequences to technical and strength training in sport will be discussed subsequently.

A changing understanding of causality – system dynamics

A main characteristic of this systems dynamic oriented approach is putting the focus rather on the changes of states in time than analyzing the stable states. Basic influence on the development of the systems dynamic approach is found in non-

linear dynamics, synergetics, catastrophe theory, theory of complexity and neurophysiology. The influence mainly resulted in a different understanding of the relation of cause and effect as well as the emergence of structure and order. In the classical newtonian or reducionist understanding cause and effect are considered in a linear relationship. Consequently, learning and training processes were investigated and interpreted primarily on the basis of linear relationships. In the weak formulation the understanding of linear causality demands the assignment of identical causes to identical effects. Transfering this to the learning or training process, one would expect that every athlete would react to an exercise or instruction in an identical way. This understanding of causality also forms the basis of linear additive training models, where it is believed, that the sucsessive training of individual elements of a single movement will result in an expected goal- or ideal movement. In a much stronger formulation of linear causality, similar causes and similar effects are assigned to each other (Loistl/Betz 1994). In contrast, mainly from mechanical bodies derived understanding of causality, the reality in training appears very different. On the one hand, in the training process big efforts often lead to minimal or no sucess, while on the other hand we can observe that a single „correct“ instruction or exercise at the right point in time can cause „real miracles“.
In the sense of catastrophe theory (Thom 1972) single events can cause real catastrophies, or the same exercise offered within other boundary conditions can lead to totally different results (c.f. Haase 1991).
Such phenomena can be explained more plausibly by means of a non linear understanding of causality. In a nonlinear relationship, little causes are assigned to big effects and vice versa. Such phenomenon are meant by the butterfly effect, which states that a stroke of a butterfly in south america can cause a thunderstorm in europe by means of nonlinear interactions. Most interestingly, such nonlinear phenomena occur much more often than the linear ones, not only in humans, but also in nature.The number of nonlinear phenomenon increases mostly by the complexity of the system. Closely related to the problem of causality is the emergence of structure or order. In analogy to most sciences the structuring of movement and ability repertoir is considered a major goal in technique and strength training. Therefore the presence of an external teacher or his knowledge of the corresponding order has been considered a necessary condition. Among others, experiments in physics and chemistry lead to rethink this kind of understanding (**Fehler! Verweisquelle konnte nicht gefunden werden.**). An experiment from Benard (1905) nicely displayed the emergence of a structure with in a liquid just be heating: If we heat up a small layer of liquid from below, roles of liquid occur as soon as a certain (or critical) temperature is exceeded. If the system is cooled down and heated up again, it can happen that the roles occur again but the direction of rotation has changed. In both cases a stable pattern emerged without the influence of an external teacher or a brain which tells the system how it has to move and without dictating a structure. The pattern or structure emerges self organized on the basis of the characteristics of the liquid. Which of the two stable states will occur is decided by accident once the critical temperature is achieved. This observation can be described by means of potentials. While at the beginning of the experiment only one stable state (main valley) exists, two stable states (two valleys) emerge when passing the critical temperature. Similar bistable behavior is known from visual tasks shown in Fig.2. Here the change between both stable states is not ruled by voluntary action (Haken/Haken-Krell 1992)

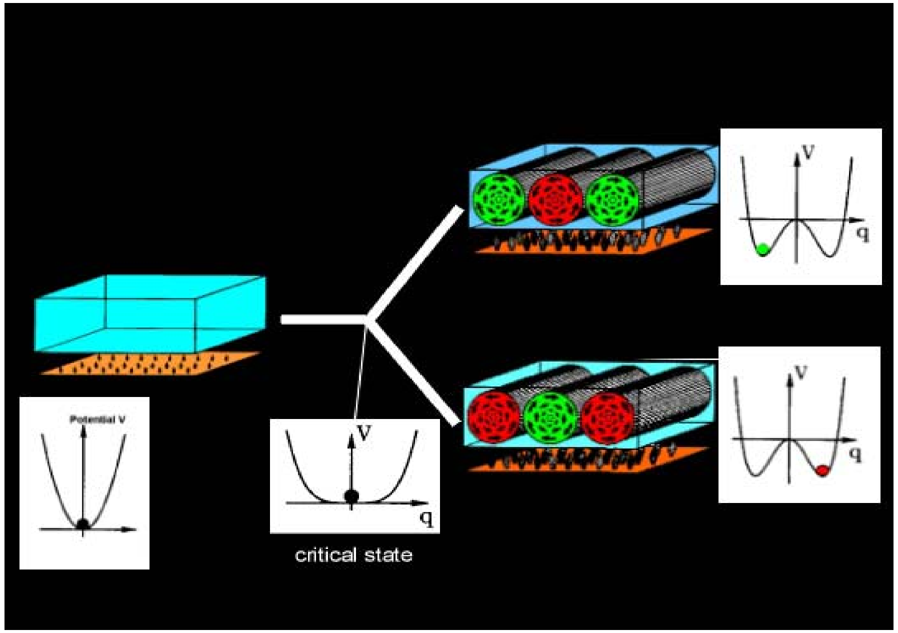

Figure 1. Heating of a thin liquid layer with according potientials

Figure 2. Bistability of ambiguous figures (vase-faces)

Systems dynamics and movements

First experiments which exposed similar phenomena in human movements were described mathematically by Haken/Kelso/Bunz 1985. Schöner/Kelso (1988) generalized the approach to learning of cyclic or rhythmic types of movement. If we move our left and right finger with a constantly increasing frequency from left to right above a certain (critical) frequency, the movement pattern changes from a parallel to an antiparallel type of movement Figure 3. This change or phase transition occurs despite our conscious effort to stay in the starting movement, and it can be observed in all people, but at different frequencies. Once this critical frequency is passed, it is not possible anymore to switch to the starting finger movements without reducing the frequency. When starting with the antiparallel movement pattern, no qualitative changes will be observed. Obviously, the systems seems to have two stable states until the critical frequency is reached and only one stable state above this critical frequency, which means that the potential possibilities are changing with increasing movement frequency.

Figure 3. Qualitative change of form of movement with increasing frequency

Considering the relative finger movements in more detail (Figure 4), fluctuations and intermittencies in both movement modes are striking. The fluctuations in the parallel mode are higher than in the antiparallel mode, and therefore the antiparallel mode has to be considered as the more stable mode. Of particular interest in this experiment is the behavior of the system during the change from one stable state to the other. In analogy to the behavior of complex non-equilibrium systems the transition from one stable mode to another is passing through an instability.

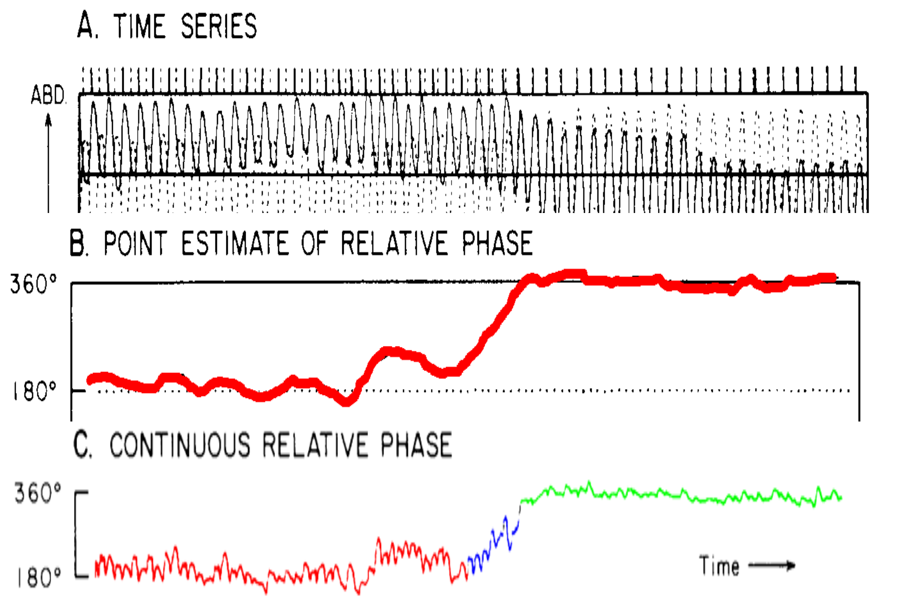

Figure 4. fingermovements (A) averaged relative phase (B) and continuous relative phase of fingermovements (C) (Kelso 1995).

Considering this behavior by means of a potential landscape, as shown in Figure 5, at higher frequencies exclusively the antiparallel mode with 0 degree relative phase with the single valley can be seen. The valley corresponds to an attractive state for the system and therefore is called attractor. In slower frequencies, both stable states (0 and 180 degree relative phase) are represented in the potential landscape by two valleys. During the transition from lower to higher frequencies the valleys of the parallel finger movements become unstable and lead the behavior at higher frequencies to the most stable and deepest valley with 0 degree relative phase.

At a first glance the fluctuations are somewhat surprising, because within the human movement repertoire this finger movements are simple ones. They provide evidence for our inability to repeat an exact rhythm for several times, and for making ‘errors‘ all the time. Furthermore, taking into account that such fluctuations occur in most (all) biological systems, we can consider these errors as a necessity for natural adaptational processes (Ashby 1956). Therefore ‘errors‘ are a requirements for systems that learn. In contrast, most machines are able to move and repeat movements without errors, but mostly they are not able to learn.

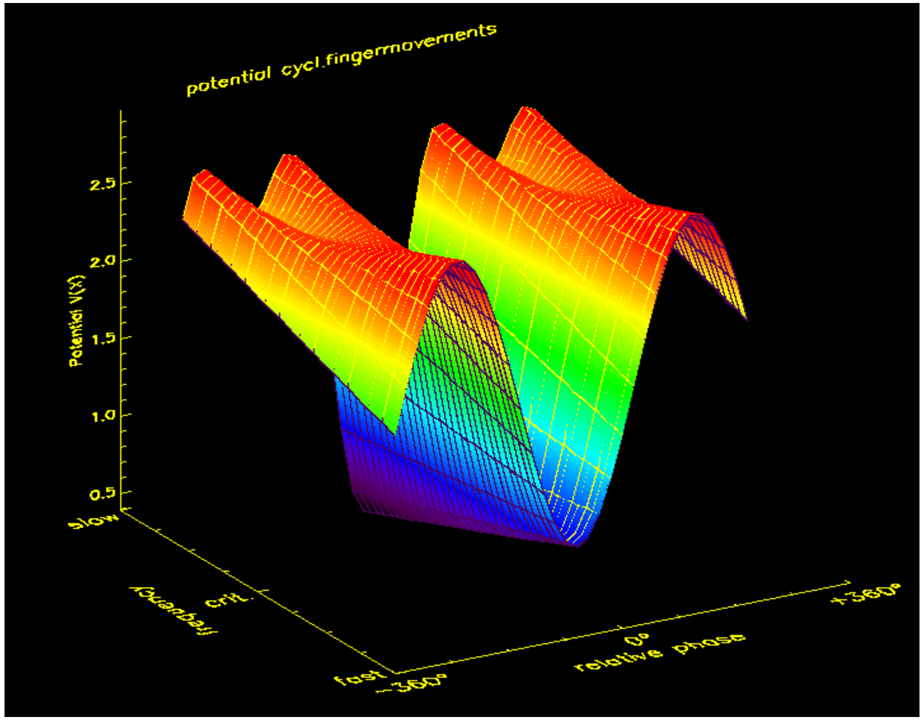

Figure 5. Potential landscape of parallel and anti-parallel finger movements with increasing frequency.

With respect to movement learning and technical training two main consequences can be derived from this experiment. One consequence is related to the movement speed at the earliest stage of learning a new movement, the other consequence is related to the transition between two stable states. In the first case it can be stated that during acquisition of a new movement the movement speed has to be below a critical frequency or in more general terms below a critical speed. Above this speed only a single potential movement pattern (mostly automised) can be produced. In the case of transition between two stable states a different time scale has to be taken, where acqusition of a new movement technique can be achieved by making the old movement pattern unstable. Similar phenomenon have been forecasted and verified for other types of movements (e.g. cyclic hand, ellbow-hand, different arm leg movements and movement learning tasks (Kelso 1995). Beside the description on the kinematic level the same phenomenon as fluctuations, intermittencies and phase transitions can be

described on the muscular and central nervous level. (Kelso 1995, Haken 1996, Fuchs Jirsa 1997).

Systems dynamics and the training of gross motor movement

For the generalisation of the systems dynamics approach on to noncyclic forms of movements we have to switch from the specific parameter of description of cyclic movements by means of the relative phase to the more general parameter of the time course similarity at ballistic movements (Schöllhorn 1994). An advantage of this generalized parameter can be seen in the posssibility to describe cyclic as well as noncyclic forms of movement. This corresponds to the quantitative analysis of variable time courses, and therefore allows the quantitative analysis of complex structured movement qualities like the gestalt of a movement, that has been difficult to qualify with a time discrete description. (A time discrete description is based on the intensities of a variable at a single instant or on the average intensity during a time interval.) The time continuous movement description contains the possibility of desribing different movements classes like running, jumping, throwing, or different modes of movement like springy or creepy walking, as well as the quantitative comparison of different movement styles (individual expressions of movement classes and modes).

The nonlinear analysis of a one year learning process in discus throwing by menas of artificial neural nets (Kohonen map) provided strong evidence for the low probability of executing two identical movements (Schöllhorn 1997). Therefore, two advanced discus throwers (junior national team in discus and decathlon) were analysed on the basis of different variable categories (instant values, range, time courses) and different levels of observation (cinematic and dynamic). Describing the final throwing phase (duration is about 200ms) by means of angles and angular velocities of the main joints (ankles, knees, hips, shoulders, ellbows) reveals constant fluctuations in the discrete (instant and range values) as well as in the continuous (time course) parameters. This means that we were not able to identify two identical movements over one year, although the two athletes were very advanced. (for the impossibility of identical movements c.f. Hatze 1986) .

Additionally, the comparison of both learning processes provided detailed insight into invariants of movements and its development. Invariants could only be identified within the time course oriented movement gestalt and did not seem to exist per se. They also did not seem to have to be trained or drilled in the sense of the schema theory of Schmidt (1975), but rather emerge from a big number of varieties and combinations of the variabel categories (instants, range, time course) and constraints. Beside the identification of a qualitative change (phase transition) of the discus technique the neural net approach revealed the identification of day dependent throwing strategies (Bauer/Schöllhorn 1997).

Systems dynamics and individuality

The application of the same nonlinear pattern recognition procedure to ground contact and flight phase in running lead to the identification of individual running styles for 20 athletes (Schöllhorn/ Bauer 1998a). The ground contact phases and the flight phases of a double step during running at different velocities (3-6m/s) were analysed three dimensionally. The kinematic analysis of the ground contact phases provided a 90% assignment of all running patterns of single athletes to separated specific groups. This corresponds to a 90% recognition of a person based on running characteristics during a ground contact lasting 200ms. A performance dependent running pattern could only be diagnosed occasionally.

Similar results were obtained from the analysis of 29 male and female javelin throwers from different nations and different performance levels. Here the final throwing phase (duration <200ms) were analysed using the same variables as in the discus experiment. From 2 female athletes 10 and 6 throws within 4 years were included, while from all other athletes only single trials were analysed (Schöllhorn/Bauer 1998b). Amongst all throws we were able to identify exactly the 10 and 6 throws within separate clusters. Additionally, gender specific throwing techniques could be assigned to the throwing patterns. Most intrigueingly the width of variation of the throwing patterns was larger on the international level than the variation on the national level of performance. Strong evidence to nation specific throwing techniques or throwing patterns that are dependent on an ideology comes close to this result. A dependance of the throwing patterns on the thrown distance could be diagnosed only in one case, but never between individuals.

Problems of common training strategies

The observation of continuous fluctuations even at the level of simple movements, the low probability of two identical repetitions of movement as well as the high individualitiy in beginners and advanced athletes in different types of sports leads to question the traditional ideas of technical and strenght training. Here three areas of training will be discussed which are touched by these phenomena:

1. meaning of errors
2. meaning of drill and
3. meaning of ideal or goal techniques

The meaning of errors

Here the principles of systems dynamics lead to relativize the term "movement errors" due to the fundamental influence of fluctuations on

learning processes. In principal, the usage of the term „error" implies knowledge of the „correct", and errors are generally intended to be avoided during learning processes. But if we interpret fluctuations and intermittencies as errors, then we can consider errors as a necessity for learning.

The basic role of differences for adaptational process is known very well from biology. In combination with the high individuality of movement patterns the problem of determining the „correct" also has to be taken into account, without considering the fluctuations in the movement patterns in high performance athletes. But in contrast to beginners advanced athletes seem to have a repertoire which allows them to react to fluctuations more adequatley and faster.

The meaning of drill

The problem addresses the function of the automatization process or the goal the process is directed to because of the low probability of two identical movements. Certainly, by repeating the same movements, great successes were and will be achieved. In the same way, by numerous repetitions and due to the low probability of identical movements a certain variation around the 'goal' or 'ideal' movement will be achieved (in a high dimensional space). Also, within this numerous amount of trials the athlete will find more or less accidentally his or her 'optimal solution'. But it is still unclear, if the success is caused by the number of repetitions or by the size of the variance. If the success is due to the variance, a great chance for the creation of a more effective training process is provided.

The meaning of goal- and ideal techniques

Here problems arise on the one hand due to the identification of individual movement patterns in beginners and advanced athletes, and on the other hand due to the evidence of nation specific or ideology dependent movement patterns. If we assume that world class athletes have found their instantaneous and very individual optima, and at the same time individualtiy can be identified in beginners, then we encounter the problem of teaching young athletes certain sport techniques that are no more adequate for their body or do not fit their mentality when they are grown up (e.g. skiing techniques). The possibility of developing individually ideal techniques only seems plausible at first glance. On a more differentiated level the inclusion of the phenomena of fluctuation and adaptational process together with the uncertainty theory and its nonlinear interactions of its measures only provides very coarse guidelines of ideal or goal techniques. If all variables of an athlete are measured in detail in order to describe the movement exactly the variables for the subsequent movement are different from the measured one , due to the memory of biological systems. This procedure results in an endless process where the effect of the measurements and computations have to be questioned for its practical consequences.

Theoretical and practical consequences – a changed concept on technical and strength training

Finally, we are in the dilemma, that on one side it is highly improbable to avoid errors in the sense of fluctuations or intermittencies, and on the other side it is difficult to identify individual ideal techniques which are consistent over time. A possible solution is provided by a concept which is referred to in the following as „differential learning and teaching“. The concept is taking advantage of the necessity of fluctuations or errors for learning. If we consider fluctuations as deviations from a reference point, then they represent differences, which allow the system to constantly react and adapt to changing constraints. The choice of the term is mainly oriented on conditions that are generally necessary for biological adaptational processes. A major influence on learning or adaptation seems to occur though the existence of differences, which means, that a great amount of information is implicit in the difference of two stimuli. Examples can be found with paired sense organs that derive additional information from its two different stimulations. For example, from the stimulation of a single eye or a single ear no spatial information could be extracted.

Therefore, from an theory of information or learning point of view it is hard to find a plausible justification for the repetition of two identical movements. If the measurment is done with a corresponding resolution, two identical movements are not seen, not even in highly automized movements. Performing a movement twice enables the identification of a relative difference. If the same movement is performed a third time, it is located either between the first two or outside of the spread difference. Due to the high dimensionality of movements with its high degrees of freedom every new „repetition“ displays a smaller or larger difference in comparison to the previous movement. If all performed movements would be stored in a traditional point of view, we are still confronted with the problem of the next execution, because it will display a certain difference to the previous executions – existing still in a small detail.

In order to find a solution, mechanisms have to be discussed which enable adequat and quick reactions in continuing new situations with all ist novelty. Possible concepts of explanation address the mechanisms of interpolation and extrapolation as well as the mechanism of peripheral selforganization.

In this case interpolation describes a mechanism that estimates a unknown state between two known states (stored movements), extrapolation explains the estimation from two known states to a third unknown state outside the known interval. While the phenomenon of extrapolation in neuronal systems has rarely been the subject of research, numerous models of artificial neural

nets with successful and practical applications for the mechanism of interpolation have been developed. Artificial neural nets (ANN), which are basically models of neurons, are mainly trained by a ‘teaching data set‘ and tested on an unknown data set. ANNs work very well within the range they have been ‚taught‘. This means that ANNs are very successful in interpolation but outside this range do not provide the best results. Therefore, a goal is to train the ANN with data of a wide range in order to get a wider area of interpolation in the case of application (Hertz/Krogh/Palmer 1991). For example, when an neural-net-controlled robot is trained just to move forward in a given environment, then the robot is moving very well within the taught environment, but fails within short period of time when the environment changes. If some noise is added during the learning phase the robot is even able to manage unknown environments quite satisfactory (Miglino/Lund/Nolfi 1995). By training the borders (limits) of the noise, the external teacher relies on the ability of interpolation in the learning system.

The principle of explanation with respect to peripheral self organization is related to the contradiction of making a movement program perfect and modifying the program for each movement at the same time (Zanon 1997). Instead of following a strong hierarchical movement model which would expect a complete detailled programming of all movement elements, characteristics can be assigned to the peripheral movement that support themselves a broader movement goal. As a consequence of this assumption the contradiction is solved. By means of an every day example this will be explained:

By steering a car with spring-loaded air wheels over different surfaces the driver needs only a coarse orientation on the streets limitations. The spring-loading as well as the air wheels will damp possible unevenness by its characteristics such that the drivers cabin will almost hover shock free over the asphalt. Therefore the driver does not need much knowledge about the damping characteristics of the springs and wheels nor does he have to control them in detail. Is the car equiped with stiff wooden wheels much more knowledge about the controlling of the wheels is necessary in order to move forward shock free.

In difference to a car where the constructor determines all the damping characterisitcs in advance, such ‘self organizing‘ characteristics of the periphery can be adjusted by humans. The situation specific adjustment has to be learned and continuosly adapted. The sufficiency of adjustment of certain muscle parameters for the stabilisation of a cyclic movement has ben shown most recently Wagner/Blickhan (in print). In case of a wrong parameter adjustment either a catastrophy or a standstill results. Loeb (1995) designates such a pre-adjustment with preflex. This can be interpreted as a continuous adjustment in advance and allows fast and adequat reaction to new situations without including higher controlling institutions of the central nervous system. This „adjustment in advance“

of the movement system can be considered as a continuos estimation (interpolation) of the future on the basis of the previous, or as a shortterm attitude that expects the coming. It serves to provide an immediate, as fast as possible reaction to new situations.

The process of such fast reactions is highly probable and supported by the ability to execute the movement without conciousness, and is often described by automatisation of movements (Daugs 1993). Instead of rejecting the previous acquired, conciously controled part of the movement, the differential learning approach is aimed at acting more effectively though the unconcious mechanisms of learning and reaction from the beginning. The goal is not to make a detour from unconcious movement over totally controlled concious movement, but rather keep the unconcious part on a higher level and just be accompanied by little consiousness. Analogies to the motor learning process in little children can be seen here (Thelen/Smith 1993). Within the first two years of life little children learn as much as no other system known in biology, physics or chemistry without using much consiousness or getting any external instructions.

Practical consequences

In analogy to potential differences in the adaptation of biological cells, differential learning and teaching is focusing more on the athletes‘ ability of interpolation by screening the borders of the scattering range and on the athletes‘ possibility to select, conciously or unconciously, from a big number of exercises that single or group of exercises which fit the momentary state best. By executing possible „errors“ in all combinations the area of the individual optimum will be found „by the athlete himself“.

Differential learning does not imply the abundancy (redundancy) of coaches or teachers nor a totally arbitrary trial and error learning or the explicit learning of „errors“. In contrary, differential learning covers the whole area of possible fluctuations. It includes learning by contrast and includes the knowledge of the whole area of possible solutions with an immediate comparison with „errors“ as well.

The central content of differential learning is learning on differences by means of most versatile exercises. In order to explain the difference in comparison to Schmidts‘ variablity of practice theory we compare the possibilities of training four different exercises within one training session (Figure 6A). On the ordinate-axis the similarity of exercises A to D relative to a reference movement is displayed. The reference movement can be any movement but in most cases it is the movement which should be finally achieved. On the abscissa axis the time history of a practice or training session is shown, where the schedule of 10 repetitions of each exercise represents a blocked/variable training approach. At the end of the session 4 times 10 exercises will be performed. The coordinates distance between exercise A and exercise D corresponds to a measure dv for the variability of all exercises. In Figure 6 the same four exercises are given with the same variability dv but with three characteristic changes on their time sequence. The single exercises are no more just repeated 10 times before the next exercise starts, but rather are put into different time orders (designs): in design I) every exercise is perfomed once before the same exercise is repeated, in design II) a certain number of repetitions of one exercises have to be performed, and in design III) the sequence of the four exercises has changed. If the designs I) - III)are repeated several times the sum of all exercises will equal the number of the design in Figure 6A. Most intriguingly, the variability dv in all designs is still the same. Thus the changing variable in each design corresponds to the magnitude of all adaptations. In Figure 6A the main and largest adaptations (dashed arrows) have to be made at the beginning of each block of exercise (four). During one block of exercise the magnitude of the adaptations decreases with a descending exponential function (Mayer-Kress et al 1998). The same magnitude of adaptations appear in Figure 6B in each of the three designs, but in contrast they do not only occur once but several times.

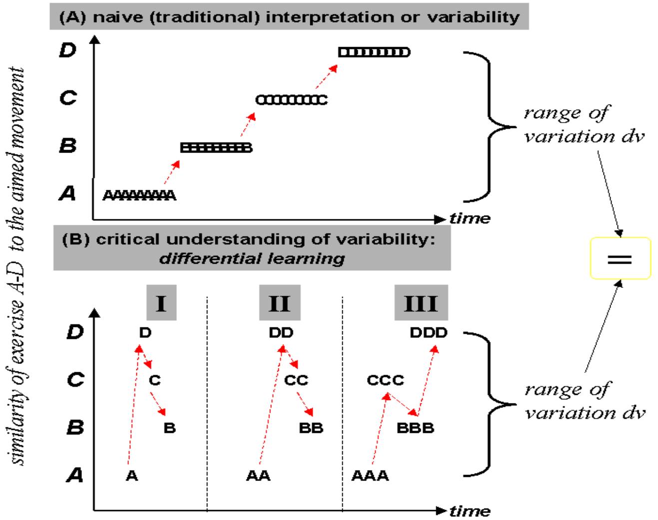

Figure 6. Training designs with four different exercises A-D and identical ranges of variation dv in a naive (A) and a critical interpretation (B) of variable training

Assuming that the number of repetitions or just the magnitude of adaptation not only cause separate effects, but both work together, each design in Figure 6B displays advantages in comparison to the mixed block/variable practice approach as shown in Figure 6A. By considering the magnitude of adaptation as one crucial factor for learning progress the emphasis is more on larger differences between movement executions, and therefore the focus is rather on the adaptational process than on the movement itself. When the athlete is confronted with, and learns from continuos changing conditions (=differences), it has to be questioned, wheather the movement has to be learned or the ability to adapt? From the adaptational point of view the eastern saying „The way is the goal“ brings in a most intriguing factor for movement learning. When the next movement will be new anyway, what else do we need in a new (next) situation than the ability to adapt to this new situation? In order to adapt fast the adaptational process should be learned at least to the same extent as the movement which has to be produced and therefore differential learning seems to be more suitable than performing drills.

By amplifying the fluctuations during the acquisition and the automatization process, a selforganization process should be launched by the athlete himself.

Thus, systematic indications for proceeding in differential learning in technique and strength training could be:

- variation of initial and/or final conditions of a movement
- change of variables range
- changing of a movements time course with respect to relative and absolute duration and rhythm

Initial conditions are varied in walking for example by walking with bent knees. When we walk with shorter or longer steps, fast or slow, then primarily the variable range is changed. Walking springy or creepy is changing the movement time courses. In a first approach, this three possibilities of variation can be applied to every joint to following parameters

a) joint angle
b) joint angular velocity
c) joint angular acceleration.

In combination with the exclusion of certain extremities during a movement or in combination with changing internal boundary conditions like muscular fatique or psychological states of arousiness the amount of differentiation possibilities becomes enormous. The number of possibilities of successful

learning is going to become even bigger when not only the borders of the scattering range in every joint and variable are executed but also their combinations and executions between the extremes. The structuring into a)-c) possibly provides some indication for a longterm learning strategy in technical training. At the beginning of a learning process primarily the geometry (angles) should be varied, while the advanced will rather vary within the velocities, and the highly skilled athletes should vary the accelerations and rhythms of the joints. Application of this concept to the example of running leads to differentiation of stride length or movement amplitude at the beginning (e.g. long steps with short arm swings and vice versa). Afterward, the focus of differentiation can be put on the movements velocity (e.g. right side fast – left side slow or switching from low to high step frequency and vice versa), and in an even more advanced state of learning the rhythm and accelerations can be varied (e.g. switching from active foot-ankle work to hopping or changing from step jumps to running and vice versa). In every state of learning additional variation in all three variable groups should be applied. In differential learning a specific role is assigned to the coach or teacher by adapting the range of variation or changes to the individual conditions of the athlete, which is very likely to vary between days (for more examples in sprint running see Schöllhorn 1995).

During a medium and longterm training process the concept of differential learning is applicable in a similar way with different timescales. When a certain range of variation has been applied to a certain period of time the „variation has to be varied“, too in order to reveal a new difference on another time scale. The multiple repetition of the „same movement“ represents a special form of differentiation. The time scales of application are primarily oriented on the biological times of adaptational processes and rhythms: for muscles this timespan comes to 4 weeks, for ligaments and tendons three to six months, and for bones and cartilage up to one year. However, these adaptation times do not depend exclusively on their duration but are rather overlayed by individual rhythms as Reiss (1997) could demonstrate most impressively with the dependence of the strength increase upon the menstruation period.

The concept of differential learning and practicing represents a generalisation of Schmidts‘ (1985) variability of practice theory, but is based on biological and physical principles. In difference to Schmidts Hypotheses of variable practice, differential learning is not only directed towards the stabilisation of an already existing single generalised motor program (GMP), but includes also variable and differentiated applications as well as the discovering and development of individual (time dependent) „generalised motor schemes“. GMPs represent theoretical constructs, which describe communalities of groups of movements and serve as metaphors for central nervous processes during movement executions. Due to the continuous fluctuations of biological systems, fluctuation in the GMPs are highly probable and can be assumed as such, too. By performing and practicing different generalised motor programs, and not only one program with variable parameters, the athlete should get prepared for more new (!!) situations and therefore should be able to perform intended movements more stable. The variable offering of exercises is moving from discovering over forming up to stabilising movements, from the manifold geometry (spatial gestalt) over the velocity (time-spatial gestalt) up to the variable accelerations in movements. Just by offering alternatives a system will get the chance to compare and eventually select. The less possibilities are offered the higher the danger of movement stereotypes, which represent not optimal solutions because of their inability to adapt to changing conditions. In a potential landscape, movement stereotypes can be considered as local minima whereas the training process is searchig for absolute minima. By offering a bigger dispersion of exercises, the probability of finding an absolute minimum, which fits the individual, is increasing. Local minima represent solutions, but in contrast to absolute minima they are not very well adapted to the individual‘s characteristics and therefore are less economically and less effective. By using differential training the athlete is learning how he has to react to a specific situation. He is learning about himself and his body though confrontation with the environment and will not become the performer of a strange idea.

An athlete will be prepared right from the beginning to react to countinuosly new situations (fluctuations) in a fast (unconciuos) and adequat way rather than to physically predetermined conditions, which will only occur twice with an extremely low probability. Fast and adequate reactions to new situations are well known in highly skilled athletes and can either be achieved by an enormous amount of repetitions within similar boundary conditions or by interpolating from known extreme situations and resulting adequat peripheral preadjustments. In the second case the learning process can be shortened drastically.

Besides being advantageous for individuals, offering diverse exercises provides additional benefit for teaching or coaching in larger groups (training groups, or school classes) by talking to several learning persons in their own „body language“. If only one single exercise is offered to a whole group the probability is very high that only a few group members are responding adequatly to the teacher‘s expectations. With an increasing number of offered exercises the probability increases of having one exercise for every group member where he/she will respond to in an adequate way. An important role comes to the concept with respect to motivational aspects.

The bigger variety seems to better meet the natural curiosity of humans, which allows very successful learning during the first two years of life.

After many general, and mostly qualitative lip services for individuality, several approaches for qualitative descriptions of individual characteristics (a.o. Körndle/Lippens 1984, Mester/Perl 2000) and rarely noticed quantitative evidence of individual muscle characterisitics (a.o. Gutewort/Sust 1989) or individual physiological parameters (a.o. Busse et al. 1991, Busse et al. 1992) demands for quantitative individual training and teaching in the area of coordinative aspects are posted too (Schöllhorn 1999a,b).

For future research more focus should be put on individuals. A separation of boundary conditions and characteristics of the system itself in research, especially with respect to principles of training, should be supportive on the way to find regularities and laws for individuals. Once we not only start this effort in an advanced age of training, but already in the field of beginners, the differential learning and teaching approach offers a chance, to improve the quality of training in the sense of the physical principle of resonance. Primarily, systems which work in harmony reach best performances. Nevertheless, are not the best athletes distinguished by „knowing“ themself and their body like no-one else, when and how much they can and have to burden. And, are not the most successful coaches distinguished by their ability to develop different adequate concepts for every athlete or every team?

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