The following is my translation of portions of *Models of Motor Movement* by Juergen Birklbauer. It is an attempt to explain advances in research into specifically animate motor movement and distinguish it from the inanimate, Newtonian physics which have placed severe limits on our ability to appreciate and understand the complexities of movement in sport, not to mention coach effectively. I have italicized points of particular interest to nordic skiing and coaching.

Modelle der Motorik (Models of Motor Learning), Juergen Birklbauer, Meyer&Meyer 2006, 550pp.

p.116ff. **4**. **System-dynamic models**

With system-dynamic models of motor learning as well as synonymously used concepts such as ecological theories, actions theories (action approaches) or dynamic system theories, it is a matter of an integrative initiative which views the realization of human movement as a whole phenomenon as an active, goal-directed confrontation with the immediate demands of the environment and the innumerable emotional, individual as well as social factors which affect the individual.

The basic idea which remains congruent throughout the various systems-dynamic models contains the concept that the control and steering of movements originates as the result of the interaction between the segments of the body and the surrounding world. The design of a central representation, as hierarchical control- and steering models would presume, plays no role is a system-dynamic initiative.

In contrast to the structural process of the Motor Approach, which postulates the existence of central, hierarchically ordered mechanisms for programming steering of movements, the system-dynamic initiative is phenomenologically oriented and describes patterns and principles which support the heterarchically arranged and self-organizing system of movement steering.

Whereas the models of information processing, for example, in an approaching a tennis ball, see the visual information and inquire how it is picked up by the player, whether depending on ball speed varying motor programs are initiated, whether in executing the movement additional feedback mechanisms can become effective in regulating it, the system-dynamic models, on the contrary, look at the correctly executed stroke and ask on the basis of what principles the athlete succeeds in assuming the correct position at the right time.

These principles of the system-dynamic, which at first glance seem abstract, arise from the presumption to generality. Accordingly, the demand is intended to be able to describe and explain phenomena from totally different areas.

In the classic system theory the dynamic perspective is differentiated from the stationary or static systems initiative. The latter concerns itself with the analysis of systems in a quasi stable state; it investigates relationships which come about when the system is largely in balance, that is, it has enough time to come to rest. The dynamic-system analysis, on the contrary, ask about the transient processes, it concentrates on the trnsition phases between the [resting] states.

Complex systems which stand in the focal point of the dynamic-system perspective fulfill the following fundamental features:

For one thing, complex systems are open and are in a state distant from (thermodynamic) energy balance. Open systems conduct a continual energy and information exchange with the environment, in order to construct ordered states (structures)[patterns of coordination] and to be able to maintain stable (flow) balance. One terms them dissipative. This characterization originated with the Nobel laureate Ilya Prigogine, who with his theory of dissipative structures founded modern self-organization theory in physics. Without energy and information exchange the system strives in accordance with the tenets of entropy toward the state of thermodynamic balance (disorder). If after a disruption of the energy flow the flow balance can no longer be achieved, then we have an irreversible process. With living systems, for which the thermodynamic state of balance means death, such an irreversible state is present. “The moon is in equilibrium. The moon is a dead planet.”(Peters, 1991)

For another thing, complex systems display non-linear behavior; they are sensitive with respect to the initial conditions, that is, a small cause can lead to a large effect/impact.

The possibility of non-linear interaction of many system components and the open character of the complex systems are the two essential prerequisites for self-organization, which as overarching model stands in the center of the system-dynamic initiative.

p.118. According to Paslack(1991, p.20) every natural organism is characterized by being at all of its-in principle innumerable-organization levels irreducibly complex.

Loosch(1999, p.98) characterizes human movement as a complex system, “which moves far afield from balance conditions, displays an irreversible temporal directedness, and is subject to the play of ordering and control parameters.”

Motor actions are usually divided into simple and complex. In contrast to this customary categorization, Nitsch and Munzert(1997, p.53) consider it much more fruitful to grasp the degree of complexity of movements not in terms of category but in terms of metrics. In that way the degree of complexity of a dynamic-system is determined by the number of independent coordinates (dimensions) which are necessary to reach an unequivocal description of the possible changes of the system (degrees of freedom). With respect to the changes of a dynamic system the degree of freedom corresponds to the total number of alternative conditions which the individual system parts can in principle take on within the framework of the total system. In addition, the degree of complexity is dependent on a termporal component, that is, upon how fast the alternative conditions can be reached.

Related to the total movement organizaion, Nitsch and Munzert(1997, p.54) distinguish between the complexity of the movement regulating system, the movement apparatus, and the movement performance.

A system-dynamic oriented movement science reflects human movement as a complex system on the basis of its order development (coordination patter). A stable order condition of the motor system appears in the form of a high movement stability. The contradiction unit of stability and variability as a central problem of motor movement research is taken into consideration in the various system-dynamic models. Their analyses applu foremost to complex performance as a whole and not to it dissection into individual parts (cf. Roth & Willimczik, 1999, p.93).

Beside Gestalt psychology, which shifts the totality/wholeness of the observed systems and phenomena into the forefront of their interest, it is the Russian neurophysiologist Nikolai A. Bernstein as the well as the founder of ecological perception psychology, James J. Gibson, who are the originators of self-organization concept in the field of motor movement.

p. 119........

The problem of the degree of freedom (Degrees-of Freedom Problem) formulated by Bernstein (1975, p.150/1957) serves as the central theme. The execution of a specific motor task makes it necessary to chose from among the numerous solution possibilities which are available to our motor system, and thence to coordinate the superfluous degree of freedom in the movement apparatus. It is in this sense that Bernstein understands as a totality/whole the manner in which the superfluous degree of freedom of the moving organism is overcome.

This whole-oriented way of seeing was readied through classic Gestalt psychology, which recognized in its more-than-the-sum principle that the whole is something other that the sum of the individual parts.

In his ecological initiative of direct perception Gibson advocated (1986) a naturalistic understanding of the individual-environment/surrounding world-connection, since motor actions always take place in a confrontation with the surroundings. His theoretical design of affordances links with action- and gestaltpsychological concepts of Lewin and Koffka (cf. Nitsch & Munzert, 1997, 148). In accentuating the environmental component Gibson arrives at a radicallly peripheralistic view in which control and steering do not originate from the brain but from information which the human being through his self-perception receives within the environment. “Locomation and manipulation...are controlled not by the brain but y information, that is, by seeing oneself in the world.”(Gibson, 1996, p.225)

p.121. Kuenzel(1996, p.130) Conducted a sport-specific simulation of thr position shot in basketball to test the Variability-of Practice-Hypothesis. In the process the problematical nature of Schmidt's theory of a generalized motor program became obvious, that the abstraction of a straight rule in cases of mutidimensional starting conditions and movement results presents a difficulty hardly to be overcome. Facing the background that endlessly many parameters/variations are able to lead from a specific starting condition to a specific movement result makes the construction of invariants of a program have little sense.

p. 123 **4.1 Gestalt Psychology**

According to Paslack (1991, p.64) classical Gestalt psychology deserves credit for shifting whole-form concepts into the foreground of psychological models after the 19th century has been dominated by a mechanistic view.

Alongside the influence of ecological psychology, Kelso (1997, p.35) names Gestalt psychlogy as an idea closely related to self-organization: “Both views....are intimately related to the idea of self-organization, but in ways that in my view are quite complementary. Both are antagonistic to the machine stance.”

The starting point is Ehrenfels'(1890) characterization of wholeness, according to which psychological wholeness distinguishes itself through “over-summativity” and transferability. Thus perceptible whole-forms, such as melody or a geometric figure, possess their own Gestalt-quality/whole-form quality. A melody is over-summative because it cannot be explained from the sum of its individual tones, and it is transferable because in spite of the alteration of all the individual tones-for example the key-it can be preserved. The melody is thus maintained as a unit, a Gestalt-quality. (cf. Buytendijk, 1956, p.32; Roth & Willimczik, 1999, p.82).

With regard to perception Gestalt psychology was concerned with the question of what laws were according to which visual information(s) which our eyes receive are order into sensible units (Gestalts).

In the “Experimental Studies on Seeing Movements”(1912) Maz Wertheimer takes up the recognition that the whole is other than the sum of the parts. The basis for his considerations were provided by sense-deceptions. Light bulbs which lit up one after the other with a blink frequency of 30-200 milliseconds in a darkened room were unanimously interpreted as the movement of a single light source. Only at a slower frequency did the perception identify two separate events. The sum of the individual images produces a new whole (phi-phenomenon)(cf. Hill, 1998).

Wertheimer(1912) shows that with a whole it is not only something new which is added, but that the whole-form/Gestalt's parts or their characteristics which they had as single elements were lost. In this connection the determination of the Gestalt concept is not directed toward the super-summativity (the whole is more than the sum of the parts) but towards the not-summativity (the whole is something other than the sum of the parts)(cf. Iholy, 200).

Gestalts not only posses whole elements but also organization. Thus the parts have certain functions in the whole (some are essential/dominant for the Gestalt quality, other irrelevant. “The parts (for example, of the face) are relatively independent, yet meaning comes to them only in the whole. In the Gestalt/whole there takes place an interaction between the whole and the parts. The whole determines the parts, and in turn the parts have a function for the whole in that they determine the content, the sense of the total Gestalt.”(Buytendijk, p.32).

On the basis of experiments in optical perception the founders of Gestalt psychology (Wertheimer, Koehler and Koffka) and their students formulated the so-called Gestalt (whole-form) laws which determine the relation between part and whole.

The Gestalt laws according to Max Wertheimer:

The law of good Gestalt (… of simplicity or dominant character)

Human perception tends to discover “pregnant”[standing forth] figures and give them preference. Kurt Koffka formulated it as follows: “Psychological organization will be always as good as the prevailing conditions allow.” As a result the Gestalt-sort of perceptual units present the most simple and memorable Gestalt/whole-form.(cf. fig.40)

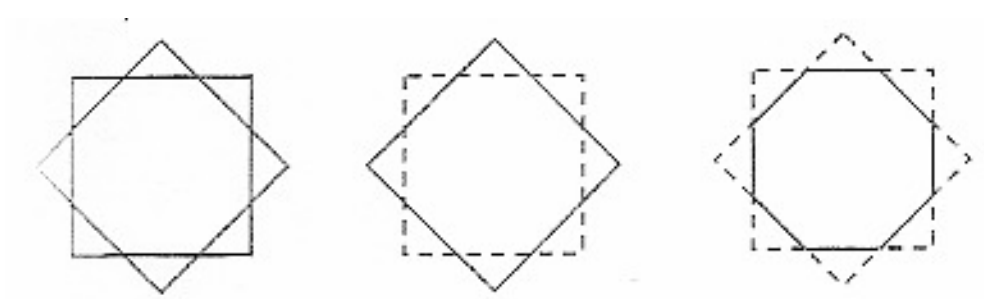

Abb. 40: Gesetz der guten Gestalt: Es werden meist zwei übereinander liegende Quadrate statt mehrere Vielecke wahrgenommen (aus Brenndörfer, 1998).

(law of good Gestalt/whole-form: two overlapping squares are seen rather than various polygons)

The Law of Proximity

Like elements (elements with the same stimulus) with the smaller distance between them will be perceived as belonging together (cf. Fig. 41)

Abb. 41: Gesetz der Nähe: Unsere Wahrnehmung gruppiert die Kreis links in Spalten und rechts in Zeilen (aus Becker, 2000).

(law of proximity:left groups as splits/columns, right as lines)

Abb. 42: Gesetz der Ähnlichkeit: Links werden die Kreise und Rechtecke als Einheiten gruppiert, rechts die ausgefüllten und nicht ausgefüllten Kreise (aus Becker, 2000).

(law of similarity)

The Law of Similarity

In complex stimulus configurations similar elements are grouped into units, that is, elements which are similar in form, color, etc., are sensed as belonging together, whereas those elements which are dissimilar are not. (cf. Fig.42 above)

The Law of Closed-ness

This refers to the tendency that in a geometric figure we sooner perceive those structures as a figure which are closed. This closed-ness can be accomplished either through actually present closed line features or through imagining them. (cf. Fig.43)

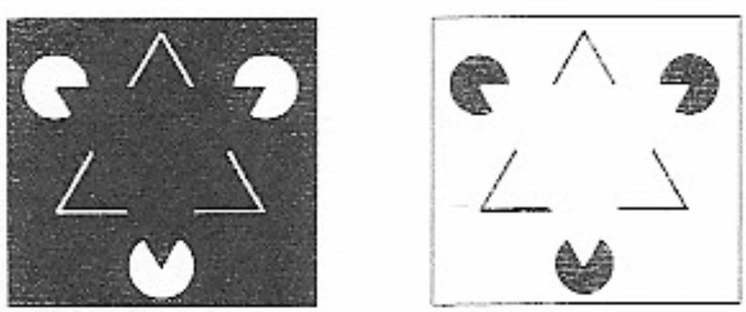

Abb. 43: Gesetz der Geschlossenheit: Die geometrischen Strukturen werden zu Dreiecken *geschlossen* (nach Kelso, 1997, S. 200).

The Law of Good Curve (….of continuing line)

Stimulus elements, ex. Points, which are arranged in a straight or softly swung cur ve, tend to be seen in connection, as lines at crossing points are seen in terms of their direction up to that point. (s. fig. 44).

Abb. 44: Gesetz der guten Fortsetzung: Die Figuren werden eher als zwei sanft geschwungene Linien, die sich kreuzen, wahrgenommen, als zwei v-ähnliche Figuren, welche sich nur berühren (nach Becker, 2000).

(law of good continuation/curve:the figures are perceived as two softly swung lines rather than two v-like figures which touch)

The Law of Common Destiny

Elements of a stimulus pattern which are subjected to a movement or change in the same direction are perceived as a unit. An example is the presentation of a ballet group which provides the impression of a coherent group through a common course of movement.

Buytendijk (1956), expanding on Mattaei (1929) describes the most important Gestalt laws as follows:

Primacy of the Whole: In innumerable experiments with adults, children and animals the immediate and rapid Gestalt perception/recognition was able to be confirmed before secondary, partial perception. An example of the primacy of the whole in perception is the capability to recognize a person in a caricature, even when it is not clear where the similarity lies; this does not happen with poorly drawn pictures.

The Interaction of the Parts With the Whole: In a Gestalt/whole-form the whole and the parts determine each other mutually. In the whole-ness (ex. A figure or melody) the parts do not stand out, on the contrary, *a distinct emphasis on the parts would disturb the Gestalt*.

The Dominating Parts in a Gestalt: Certain elements (ex. Lines, tones) or relations between parts take on a leading role in the Gestalt. Thus *a change of only a few parts can bring about a complete modification of the Gestalt* (ex. facial expression or gesture). The distinction of Gestalt-forms accords with the peculiarity of their organization.

Gestalt-forms differ with regard to the stability of the structure. With regard to the resistance which a Gestalt can exert against disruptive influences one speaks of strong and weak Gestalt-forms (up to a point of maximal disconnectedness-chaos).

Within the framework of the psychological approach of Gestalt psychology, the starting point is that the structural and dynamic basic laws in all areas of psychology are of the same or similar sorts. Optical perception, because of its graphic nature and experimental manipulability, serves to formulate and research corresponding area of lawfulness (Gestalt laws)(cf. Iholey, 2000).

In the first differentiation Metzger (cited in Roth & Willimczik, 1999, p. 84ff.) divided the features of a Gestalt into three groups:

essence and expression qualities (ex. festive, friendly, proud).
structure or arrangement qualities (ex. Straight, round, angular, gliding, growing louder, continuous, discontinuous)
make-up of the material (ex. transparent, smooth, soft)

These features hold for the whole as well as the parts. *A meaning can be added to the parts through the whole (ex. A tone becomes a dominant tone through the melody) or be lost.*

One of the main criticisms of the Gestalt laws is the fact that they can only describe instead of explain, that is explain afterwards instead of predict, the origin of perceptual impressions. The meaning and the influence of the Gestalt laws is, to be sure, without doubt, their explanation, however, presents a subjective interpretation which does not have general validity, and the substantiation through modern experiments supported by quantitative methods proves to be extremely difficult. (cf. Brenndoerfer, 1998).

Besides the psychological, psychophysiological, cognitive-theoretical and methodological approach of Gestalt psychology, the idea about origin, maintenance and recovery of order characterizes the system-theoretical perspective.

Perception is not the passive image of physical things but is subject to specific tendencies-to-order which are apparent also in physical areas. According to Koehler (1920, cited in Iholey, 2000) the origin, maintenance and recovery of order can be observed whenever the parts of an area are in a mutual impact relationship. In this case excellent Gestalt-forms are created (ex. Oil drops in water) and excellent courses of events (ex. The orbits of planets).

The concept that free interaction leads to order contradicts the mechanistic theory, according to which order can only be achieved through external force arrangements (cf. Iholey, 2000, Roth & Willimczik, 1999, p. 84).

According to Paslack (1991, p.64) Koehler's initiative lacks the features of openness and unbalance which are typical of self-organization processes, since the spontaneous formation of perceptual patterns depends upon the tendency of closed systems to achieve a final balance. Thus the regulation of eye movements – turning toward the appearance of a bright spot in the dark – cane be traced to a state of imbalance in the psychophysiological region, in which case the balance is restored by the iris being moved along continuous sensory feedback processes, so that the light beam coming from the point falls into the center of the retina.

4.4.1 Gestalt Psychology and Movement

According to Koerndle (1996, p. 102f.) Gestalt-theoretical initiatives to the regulation of movement start out by asserting that internally represented control processes serve to stabilize and maintain the achievement of the movement Gestalt through the coordination of part processes. The contents of the internal processes, however, neither fix all the degrees of freedom nor are the degrees of freedom exclusively determined by the context.

The reduction of motor complexity succeeds, so Koerndle(1996/I, p. 103), as in synergistics (cf. ch. 4.5). In complex systems, as, for example, the perception and movement of organisms, ordering processes are assumed which must be neither completely planned of internally represented but are rather determined solely by some few control processes.

For Loosch (1994/I, p. 23) these Gestalt laws at their center present us with nothing less than system-immanent structuring principles, which in modern self-organization theories play an important role under partly other names.

Nitsch and Munzert (1997, p. 59ff.) as well as Loosch (1994/I, p. 23f.) attempt a constructive consideration of the analogies between Gestalt laws with respect to motor movement, although – as Loosch emphasizes – 114 classical Gestalt laws (Dorsch, 1970) and 744 non-summative concepts (Rausch, 1966) make clear the problems with such an undertaking.

The Law of Good Gestalt and Strategy Formation – The law of good Gestalt corresponds to the observation that movements with the same result often are carried out very differently, that is, one and the same performance can be realized by means of differing structures. “For example, less force can be at least partially compensated through more favorable lever relations, lesser skills through greater effort, a lower movement potential through better application or producing more favorable opportunities.”(Nistch & Munzert, 1997, p.61). In similar fashion we are able to produce equal movement performances through the combination of various parts of the body, muscle groups and joints (motor equivalence – cf. ch. 1.2.2.5)

The achievement of the same goal situation under differing conditions (equi-finality) distinguishes *living systems from physical systems*. [rt. The distinction between dynamic/living vs. stable/mechanical seems fundamental to in undertstanding technique.]

Transferability and Individual Invariance Formation. The transferability of movements is demonstrated in that whole-structures, ex. relation of the times, forces, parameters and sequences of their parts (relative timing, relative force application, sequencing – cf. ch. 1.3.1.2), do not change within specific limits (they possess invariance, Gestalt stability).

Non-Summativity and Variability of Part and Whole. “The quality of a movement does not derive from its single components but rather from their prevailing relationship, that is, the total can have features (new Gestalt qualities – cf. Fig.45) which are not to be deduced from the summation of the features of the parts.” (Nitsch &Munzert 1997, p.59) Thus the coefficient of variability of the goal quantity in goal oriented movements is in no way represented by the sum of the variability of the parts. “In contrast to the much greater fluctuation of the parts, the whole is stable.”(Loosch, 1994/I, p.24)

On the other hand, if the variability limits of the movements of individual parts are even slightly exceeded, a break down of the total movement takes place. The whole is substantially more sensitive with respect to the parts. According to the principle *small cause-large effect*, minimal fluctuations of system elements can produce qualitatively new conditions of order – as described in self-organization theories (cf. ch. 4.5)

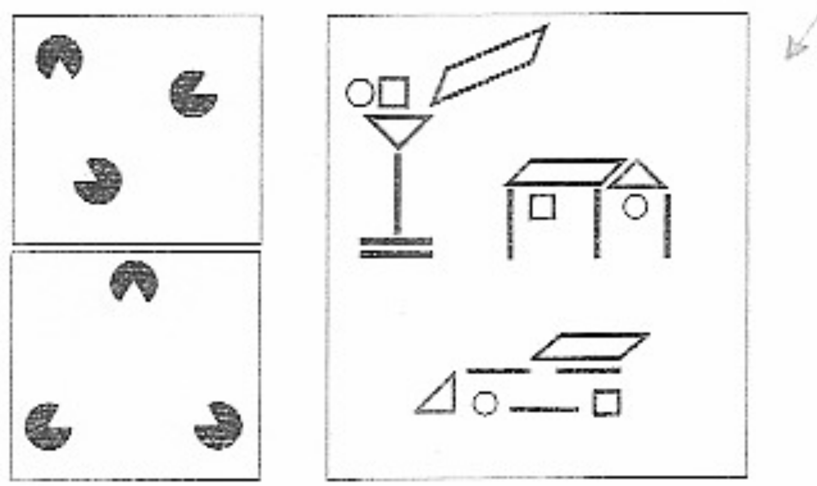

Abb. 45: Entstehung von Gestaltqualitäten in Abhängigkeit von der Konfiguration von Elementen (linke Grafik aus Nitsch & Munzert, 1997, S. 60)

(origin of whole-form qualities in dependence on the configuration of elements)

Interaction Between Part and Whole. During the learning process the connection between the part and the completion of the movement strengthens and becomes more differentiated. At the same time the correlation between part and whole sinks as the expression of increasing independence of the whole from the parts (cf. ch.4.1.3).

Figure-Ground Relationship. In general the figure-ground relationship describes how the features of the parts and Gestalt (figure) are dependent on the prevailing context or relational system (ground) in which they exist. According to Nitsch & Munzert (1997, p. 62) problems arise for the attentiveness in the execution of a movement, for individual perception, and not least for the origin of mistakes, if the context is inadequately determined (large or small, loud or soft, fast or slow, strong or weak, etc.,- depends upon the underlying context), if no sufficient differentiation (contrast) is given (clarity, recognizeability and the creation of perceptual and movement Gestalt/whole-forms depend upon the prevailing background) and if the figure-ground relationship is flexible (cf. Tip-phenomena in pictures puzzles or cognitive restructuring techniques). [rt. ex. Depth-perception tests with subtly different colored dots.]

4.1.2 Motor Movement Research of Whole-Form Psychology in the 20's and 30's.

Under Otto Klemm – who held the chair for applied psychology at the Leipzig Institute for Experimental Psychology from 1925-1935 - the theoretical framework for whole-form theory and Gestalt psychology made its way into motor movement research.

Besides Bernstein's movement studies on work psychology in Russia (cf. ch. 4.2), the concept of Gestalt theory experienced a systematic experimental review in motor movement in the investigations of Drill (1933), Stimpel(1933), Voigt(1933), Haferkorn, Oeser(1936), Pankauskas (1936) amd Steger(1938). The foremost aim of the studies was not the search from practical usable information about the regulation of movement but rather,....., the search for universal lawful principles, which one assumed would also appear in motor movement.(cited in Loosch, 1993, p.27)

Drill(1933, cited in Loosch, 1993, p. 27) undertook a movement analysis by means of chronocyclographic procedures of more than 140,000 striking movements of mechanics, fitters, smiths, cabinet makers and truck drivers. With the help of a camera an oscillating light fixed to the balance point of a hammer could photograph at 90-100 pictures a second and a detailed three-dimensional analysis of the movement structure be made.

One of the main results in the individual trials was produced by a comparison of the movement variability of the component parts with the total movement. The results showed that the scatter of the total strike duration is smaller than the mean scatter of the times for lifting and striking movements as separate variables.

The continuation of his studies to cooperative motor movement – two people work a piece on an anvil with opposing strikes (cooperative rhythm) – lead to similar results. The actual scatter of times between two strikes of both workers following each other was significantly smaller that the claculated scatter put together from the scatters of the time duration of the single strikes of each person (square root of the sum of both single scatters). *The whole thus proceeds more precisely than its parts*.

Stimpel (1933) analyzed the angle of throwing release and release velocity in throwing an ivory ball at a target 5 meters distant with children age 10-11 as well as members of the institute. Analogous to Drill, the theoretical scatter of the throws around the target was calculated on the basis of the scatter of the parameters of the parts (throw release angle and velocity) and compared with the empirically observed scatter. Similarly to Drill's results, the actual scatter was smaller than the calculated scatter. “The target was it more exactly than the variability of the parts would have lead one to expect.” (Loosch, 1993, p.28)

On the basis of calculated correlations between parameters of the parts Stimpel concluded that the stability of the whole represented the product of the interacting coordination/timing of angle and velocity (cf. Loosch, 1993, p.28)

According to Loosch (1933, p. 29) an apparently universal principle of movement regulation seems to have been discovered: “*Constancy of a goal performance is linked to the larger variability of its constituent segments.”*

4.1.3 The Renaissance of Gestalt Psychology in Motor Movement Research

Loosch (1991), in the tradition of Leipzig wholeness psychology, again took up the dialectic between part and whole in relation to the stability and variability of movements.

A question which for a while remained unanswered in the early movement studies of wholeness theory has to do with the *problem of constancy in spite of variability versus constancy through variability.* Does the greater variability of parts simply represent a functional mistake variance to be compensated for, or a necessary condition for the stability of the whole?

Referring to Berstein's postulate of the ambiguity of motor center and periphery, Loosch (1995) modeled motor moevemnt as the phylogenetic evolutionary product of a concretized/objectified function which is used is goal-directed movements *without the pre-programming of all the details being required.* In his concept of functional variability goal-directed movements are not the result of a constancy elevated to rigidity but rather purposeful interactive adaptation of the parts to reaching the goal. *Variability is not a factor of mistake but the necessary element of final stability.*

To confirm his model Loosch (1994/II) used dart throwing as an organically valid and goal-directed task...........

A fundamental hint to explaining the question introduced in the beginning, whether constance is reached in spite of or through variability, is provided by comparing the subjects of differing qualification.

With increasing level of performance at first a decrease in the standard deviation throughout all parameters can be observed. The subject with the highest performance level – a competitive player – exhibited however an almost opposite trend. Although standard deviations of the segment parameters elevated, the target precision improved simultaneously. *At a certain performance level the variability of the segments/parts appear to gain increasingly functional meaning for the stability of the movement result. This observation stands in clear accord with Bernstein's second stage of coordinative release (from freezing to freeing – cf. ch. 4.2.1.2)*

…....................
…....................

p. 141. Stadler et al. (1996, p. 148ff) undertook the attempt to apply the Gestalt-theoretical principle of conciseness [Prägnanz] to motor moevement. In the sense of the Gestalt law of good curve/continuation in perception, formulated by Metzger (1986), it was tested whether space-time courses of movement develop in type and manner that an optimal management of the existing kinetci energy is assured.........

"On the level of behavior phenomenology it is possible to describe this rhythmical structure as an emphasis of the larger amplitudes and a suppression of the smaller amplitudes. And on the level of kinetic energy a management of kinetic energy between energy rich movement cycles is made possible through this space-time formation, which confirms the validity of the described principle of the utilization of kinetic energy in movement control."

These results agree with the observations of Bernstein...as well as Konczaks that reactive forces can be used with an increasing level of performance. (cf. ch. 4.2.1.2)

4.2.1 The Problem of the Degree of Freedom

The problem of the degree of freedom (Degrees of Freedom Problem), likewise called the Redundance Problem or sometimes the Bernstein Problem ….articulates the difficulty of control, otherwise known as overcoming the superfluous degree of freedom.

In general one can understand the notion of degree of freedom as a multitude of unfolding possibilities of a system.

Bernstein (1975) came to recognize that the human movement apparatus has at its disposal a much greater number of body joints and muscles which move them than appears necessary for the solution of a specific motor task. The question which arises is how the human system is able to control and coordinate this superfluous degree of freedom. (….how the very many degrees of freedom involved in a particular act are mastered....how to reduce the number of independent variables to be controlled. (Turvey, 1991)).

In this sense Bernstein (1975) defined the coordination of movements as "the overcoming of the superfluous degree of freedom in the moving organism, in other words, its transformation into a steerable system. In short, coordination is the organization of the steerability of the movement apparatus."

4.2.1.1 Type and Scope of the Degree of Freedom

From the biomechanical point of view, the movement apparatus of man possesses three levels of freedom – for one a cinematic degree of freedom, which depends upon "the multiple segments of its interconnected cinematic chains," for another as so-called elastic degree of freedom, which is given rise to through the elasticity of the moving muscles and as a result through "the lack of clear relationships between the measure of activity of the muscles, their tension, their length and the speed of the change of their lengths."

…..............

According to Turvey (1991) 10 to the 3rd power muscles function together in order to move the joints of the human system, so that a high jump using the Fosbury flop can take place.

4.2.1.2 Three Stages of the Learning Process: From *Freezing to Freeing*

Bernstein's formulation from 1975

a) **Freezing**: Fixation/Fassening down the superfluous degrees-of-freedom.

For Bernstein coordination consists of overcoming peripheral indeterminateness, thus the main difficulty in coordination arises from the extreme fullness of degrees of freedom, which the center cannot handle.

As a consequence, as one begins to learn, one tries to reduce the number of the extent of freedom at the periphery to a minimum, as one *resorts to all possible detours*- thus it can be observed that beginners try to tense the movement extremity or the whole body and hold it as rigidly as possible, in order in this manner to eliminate a series of cinematic degrees of freedom, or to lesson from the start the number of degrees of freedom with which one has to contend. The movement at this stage is thus angular and awkward, the body position and imitation tensed, the breath constrained.

b) **Freeing**: Loosening the fixation of the superfluous degrees of freedom (1st stage of freeing).

As soon as the organism masters the first degree of freedom, according to Bernstein, in the course of training the artificial fixing of the degree of freedom, which in novices can be observed in the form of a tensed restraint, loosens. Since the fixing comes with a high consumption of energy, in this phase an improvement of the economy of the movement happens and a lowering of fatigue. Still, in this transition stage the central nervous system is overburdened by the necessary attentitiveness, and movements (extra movements) which are singular (many angled), less effective and unnecessary arise.

c) Optimal **Use of Reactive Phenomena** (2cnd stage of freeing up coordination):

The highest stage of freeing up coordination reaches a level "where the organism no longer fears the reactive phenomena which appear in the system with many degrees of freedom but rather where it is in a position to build up a movement in which the reactive phenomena which are encountered are maximally made use of," that is, the mechanically reactive forces - a sort of rebound forces which arise from the muscles' elastic features – are utilized in a positive way. Those types of movement are described by Bernstein (1975) as *dynamic stable movements*. For him this is the biological justification for the wealth of cinematic degrees of freedom in higher mammals and a proof of the possibility of a level of coordination where this wealth is of immediate use.

In this regard Bernstein understands *motor learning as active reactivity* (cf. Hirtz, 1997).

4.2.2 The Whole Character of Living Movements:

According to Schoelhorn (1997), Bernstein's early systematic manner of obeserving human movements has been influenced by the whole-ness concept of Gestalt psychology. In the same manner Reed (1984) characterizes Bernstein's approach as a Gestalt-theoretical concept (s. Munzert, 1989). Bernstein (1975) places the whole-character of movement coordination in the foreground. The appearance of whole-type blendedness happens in his particular view particularly in the analysis of automatized rhythmical movements. Ths Bernstein pointed out in studies (1926, 1934) of the striking movement of a hammer the invariance of the movement result within simultaneously substantial variability of the movement of the arm segments.

Bernstein (1975) considered the living organism a morphological object (that exists in the coordinates *x,y,z* and *t*) and living movements as a biodynamic fabric/tissue/web. The whole-character of his way of seeing things is expressed in his view that *movements are not described as a chain of details but rather as a structure subdivided into details.* [Motorik 148] The whole-structure possesses at the same time a high differentiation of its elements and different elective interactions between them. Thus the change of a detail (ex. a minimal change of the movement path of the elbow) can draw in a series of other modifications with it (ex. The form of the movement path of the hammer, velocity relations between wind up and strike or between hand and hammer), that is, the effect must not necessarily be proportional to the cause; a small cause, for example, can achieve a large effect. "The movement never changes due to the influence of a detail through the change of a detail. It responds to the change of every tny unit as a whole, in which case very clear changes in such parts occur which are far afield from the primary changed detail sometimes both in space and time."(Bernstein, 1975)

[Motork 165]

4.3.1 Ecological Perception Theory According to Gibson

…..*Perception* is not to be understood as a passive but rather directed process and thus as an *exchange of information*.

…......

….The perception of an object depends unavoidably on its function – it is not the object by itself which is perceived but its contextual function.....(Kelso, 1997) formulates it sharply: "The point is that context is everything. Remove context and meaning goes with it."

…........

[Motorik 218] *Schoellhorn (1999) interprets the linear understanding of causality, derived predominantly from the observation of mechanical bodies, as the basis for additively constructed training models. A sequential training of the individual elements of a movement does not have to lead per force to the desired goal movement, which can be recognized by considering that often a greater effort achieves minimal changes, while small instructions or training exercises at the right point in time bring about an entirely different movement result.*

[Motorik 237]
4.5 Synergetics- the Tenets of Interaction

Synergetics can be considered the most comprehensive theory of self-organization up to this point in time. It was developed in the early 60's by the German Hermann Haken in connection with the theory of the laser which came from him.....The concept of synergetics attempts to discover unified fundamentals (principles) from which it becomes possible to understand how structures come into being.

Relating to an array of phenomena in sport and human movement, in the 80's and 90's synergetics entered sport- and movement science. "Human movement in this sense is a complex system which moves far afield from balance states, displays an irreversible directedness and is subject to the play of order- and control parameters." (Loosch, 1999)

At the center of synergetics stands the emergence of new qualities through self-organization. In a manner similar to Gestalt psychology, analysis is to uncover the fundamental principles of intrinsic organization processes for the origin of order and structure: "...the important role of intrinsic orgranizational processes resonates strongly with early Gestalt theory in psychology, which sought natural principles of autonomous order formation in perception and brain function." (Kelso, 1997) Through interaction of single components new structure can originate, which cannot be derived from the characteristics of the individual participating components. These new qualities are not forced from the outside but are achieved in the manner of self-organization. (cf. Roth & Willimczik, 1999)

The concept of self-organization, according to Maghill (2001), means that specific stable patterns of behavior originate from the interaction of their elements whenever a situation is characterized by certain conditions. For example, hurricanes form, although there is no *hurricane program* for the universe. They develop only if specific preconditions of wind and water are present. "When these variables achieved certain characteristics, a hurricane will self-organize in a distinct, identifiable fashion."

Kelso (1997) lists the following elementary principles and determinants of self-organization:

- Structure (order) comes forth spontaneously out of the interaction of many parts. The premise for their origination is a large number of elements and the possibility of non-linear interaction. "...the motion of the whole is not only greater than, but different than the sum of the parts, due to non-linear interactions among the parts or between the parts and the environment."

- The system must be dissipative (open) and far away from thermodynamic balance. Because of dissipation many degrees of freedom of the system are suppressed and only a few contribute to the behavior. Dissipation is as it were an *attractor** which can assume various forms. [*attractor is a central idea which I expand upon in an appendix]

- The degrees of freedom which characterize the origination of structures in complex systems are called in synergetics collective variables or ordering parameters. The ordering parameter arises out of the coordination of the parts and the influences in turn the behavior of the parts (circular causality).

Ordering parameters are to be found close to the phase transition points in un-balanced systems, upon which the loss of stability brings about new or different structures, or a change of structures. Ordering parameters can as well exist distant from transition points, but it is difficult to identify them.

Fluctuations continuously explore the stability of the system in order to discover new or different ways to solutions. Fluctuations are inherent is all natural systems. Fluctuations are positive sources if *interference* and not something to be hindered.

Parameters which direct the system through various states/structures, but (contrary to ordering parameters) do not depend directly on the structure itself, are called *control parameters*. Such control parameters can be rather nonspecific, since they in no way served as code or description for the structure.

The dynamic of the ordering parameter (situation dynamic) – the equation which describes the transition between the states of the system – can have a simple solution (fixed point, perimeter cycle) or a complicated solution which contain determinist chaos and stochastic (random) aspects and thus can lead to enormous behavior complexity.

…..................................

In agreement with Kelso, Tschacher and Schiepek (1997, cit in Schoellhorn, 2003, p.42) see as the precondition for self-organization the feature of changeability (dynamic), openness and complexity; it takes place therefore only in systems which can change themselves, which are embedded in an environment which urges self-organization and which consists of a number of components and (thus) many degrees of freedom.

Understanding self-organization on every level begins, according to Kelso (1997) with the knowledge of three fundamental things:

-those parameters which influence or limit a system-dynamic
-the interacting elements themselves (*set of primitives*)
-the structure, or mode, which they bring forth (*cooperativities*)

These minimal requirements – which Kelso called a *tripartite scheme* – are necessary in order to characterize coherent or cooperative processes.

In the understanding of synergetics the ordering parameter is determined by the interaction of the system components. At the same time the ordering parameter determines the behavior of the individual parts. *The circular causality is a typical feature of self-organizing systems. Linear causality, which form the basis for most physiological and psychological models (input-output, stimulus-response), and circular causality, which supports the pattern creation in unbalanced systems, makes clear one of the primary conceptual distinctions.* (Kelso 1997, Kritz, 1992)

Feed-back concepts like the closed loop theory seem to close the circle between in-and output. This functions possibly with very simple systems which possess only two connected and mutually influencing elements. A complex system that consists of many parts woven together and reacts as rapidly as the nervous system, cannot possibly be understood as a feed-back generating system.(Kelso,

1997) The structures in unbalanced states arise through the non-linear interaction between the parts of the system. There is no feedback-regulating predetermining or reference valuse as in a thermostat. Thus there are no such questions as: Who confirms the reference value? Who programs the computer? Who programs the programmer?

"The child who breaks open a toy to find out how it works would be very disappointed if that toy was self-organized. Self-organizing systems have no deus ex machina, no ghost in the machine ordering the parts." (Kelso 1997)

[Motorik 251]

4.5.2.1 Haken-Kelso-Bunz-Model for paired finger movement

In synergetics a strategy is pursued of investigating systems in situations in which their behavior qualitatively changes. Related to movement coordination, Kaen sought out special macroscopic patterns in movement events in order to study their transitions in which the concept of synergetics comes into play.

As an example of such behavior change, Haken names the various gaits of horses such as walking, trotting or galloping. The switching of these gaits/pattern of movement shows dramatic transitions and can accordingly be described as phase transitions.

…......[finger experiment]

[Motorik 253]

The most important features of the experiment can be summarized as follows (Haken and Haken-Krell 1989):

There are only two stable and reproduceable basic patterns, either the parallel or anti-parallel (anti-symmetrical) movement of the fingers.

The abrupt transition from one of these states to the other takes place at a critical movement frequency(velocity).

Beyond this transition we see the symmetrical pattern.

Even if the velocity/frequency is reduced again, the system remains in symmetrical mode, that is, it does not return to the originally prepared parallel state. This event is called *hysteresis*.

The concept of synergetics contains in the first instance the search for appropriate control- and ordering parameters.

As a control parameter which directs the system through the various states (movement patterns), the movement frequency serves in the case of the finger experiment. For if the speed of the fingers rises, at a certain (critical) frequency there occurs a qualitative change of the movement behavior. The search for the appropriate ordering parameter, or collective variable, is much more difficult. The ordering parameter must sufficiently characterize the emergence of new structures in complex systems as well as do justice to the demand for circular causality, that is, on the one hand result from the coordination of the parts and on the other influence the behavior of those parts. "...to understand coordinated behavior as self-organized, new quantities have to be introduced beyond the ones typical of the individual components....we need a variable that captures not only the observed patterns but the transitions between them."(Kelso, 1997)

[I have confirmed the critical importance of this idea with a world-class Russian piano teacher: It is not just the notes touched but 1) the manner of touching – both contacting and releasing – coming and going – which "gets to the bottom of the tone," and 2) the manner/strategy for going from one note to the next (or one chord/note complex to the next)]
…........................

[Motorik 256] "The idea is that the nervous system supplies coordination dynamics rather than particular coordination patterns..." (Schoener, 1992)

[Motorik 261] [The concept of "white noise," movement "static." describes] random influence stemming from many other degrees of freedom of the biological system not captured by the collective variables. (Schoener)

[Motorik 262]
4.5.2.2 Absolute and Relative Coordination

In the Haken-Kelso-Bunz model of coordination differing features of various system components remain unconsidered.

Referring to the German physiologist Erich von Holst, Kelso (1997) differentiates between *absolute* and *relative coordination.* Whereas the first is characterized by a rigid coupling between the parts of a system, that is, by a constant phase relationship (cf. Fig.106a), relative coordination encompasses all the occurring phase relations (cf. Fig 106b) [Breast and tail fins of a fish is his example. Arms and legs of a skier?] It can be understood as the result of a latent and never ending struggle between the phase coupling and the individual intrinsic features of a biological sub/part-systems, which remain active in the interplay of the elements. "The basic reason for relative (rather than absolute) coordination is that the component parts of complex biological systems are seldom identical, thereby introducing broken symmetry in coordination dynamics," (Kelso, 1997)

[Motorik 412]
5.2.1 Critique of Classical Learning Theories and Strategies

From the interpretations of system-dynamic analyses of movement and learning processes summarized in table 15 Schoellhorn (1999) underlines three central points of divergence from the classical concept of technique training:

-ingraining movements
-the importance of mistake
-the importance if ideal or goal technique

Classical models oriented on information processing are not equipped to adequately explain the variations which appear in situations of qualitative changes of state in complex systems, such as the shift between different movement patters. Even if the program concept is applied broadly, i.e. tolerantly, deviations described traditionally as *natural variation* and which cannot be avoided and even can be continually observed in simple movements (coordination of two fingers), lie outside its realm of definition and according to Schoellhorn (2000) are not consistent with the program concept.

The concept of mistake implies knowledge of the correct, where neither the one nor the other can be exactly determined, without granting a considerable breadth of tolerance with regard to the individual stamp on motor actions. Generally mistakes are associated with events to be avoided, which renders understandable the popular idea of moving learning as ingraining process and refraining from mistakes.

Traditionally movements are supposed to be made automatic through the most exact possible and frequent repetition of a movement close to the goal technique. That learning progress is to be recorded with this view is, in Schoellhorn's words (1999) about as certain as that “a certain measure of scatter...around the actual goal technique is produced through a high number of repetitions and because of the slight probability of an identical movement.” The question remains unexplained, whether the success of the learning takes place through the number of repetitions or through the size of the scatter.

The rigid search for a goal- or model-technique makes no sense on the basis of system-dynamic structure phenomena either from the quantitative-technical or learning theory perspective. For one thing, even momentary optimums of world-class athletes, upon whom classic technique images are oriented, display a high degree of individuality and are combined with a forward leap in performance. Above all, the ingraining of movement techniques, which because of material development (carving technique) or rule changes (women's decathlon) lose relevance in a short time, makes little sense with beginners and intermediate level athletes, where the physical condition bases are not present. For another thing, if the divergence- and adaptation-behavior of biological beings is overlooked, chaos theory itself has impressively shown (cf.ch.III,4.4) that in complex systems the sensibility of initial conditions makes predictions possible, if at all, only with great inexactitude.

Considering these points, it seems that the goal in technique training corresponds much more to an individual ideal technique – an optimal solution of the movement task adpated to the inner and outer conditions(constraints).

5.2.2 Differential Self-Organization

In his concept of differential learning and teaching Schoellhorn(1999) proposes an approach which attempts to solve *the problem that neither can differences in movement behavior towards wholeness be avoided, nor two movements completely identically executed, nor can an individually ideal technique be determined*.

In contrast to the classic principle of avoided mistakes, differences are viewed as *mistakes* in the presence of which the system, as it were, autonomously tests whether there is a more favorable state than the one taken up to now. In this sense differences in biological life forms are understood as system -inherent and relevant to learning (necessary), since they allow an adaptation (learning) to the changing conditions of the surrounding environment. The divergences (differences) which are made responsible in that manner for learning progress between varying movement executions are therefore purposely provoked in training situations. (cf. Schoellhorn, 1997, 1999)

That a large portion of information is contained in the difference between two stimuli can be illuminated by our perceptual system. (cf.fig.160) Thus the sense organs arranged in pairs receive additional information out of the difference of their stimulation, contrary to which, for example, the spatial content of a single eye or ear would be clearly limited. (Schoellhorn, 1999, 2003)

…...................................
A simple but graphic example of the information which is contained in the difference of two stimuli is provided by our temperature sensitivity. If one lets one hand adapt to the temperature in cold water and the other in warm and then put them into a basin with medium temperature water, the one hand will feel the water is warm, the other cold. Information available to us is not an absolute quantity but rather a relative one. Relations are not formed through repetition of one and the same stimulus-condition, but rather in the presence of varying (differential) system conditions. Staying with the example of temperature sensitivity, many people are in a position to estimate the temperature precisely. In this case an abstract relations idea has formed, which allows us to correspondingly exact interpolation (estimation of values which lie between two knowns – s.below) and which is known to us as "fine touch"[Feingefuehl]. In similar fashion Schoellhorn (2003) emphasizes that the development and fostering of a marked and detailed fine touch in its essentials is achieved through the variable formation of the learning process.

According to Kelso (1997, cf.ch.5.1), in the interpretation of the phenomenon of motor equivalence similar abstract relations develop in the process of motor learning between the elements to be coordinated. A relational quantity acquired through learning is the relative phase, "....phase is a relative timing variable, an abstract relational quantity that is capable of being realized by many different effector systems."

Following that idea, abstract relational quantities of that sort would have to be better realized in movement learning through the introduction of differential exercises – a view which agrees with the variability-of-practice hypothesis of Schmidt (cf.ch.4.4)

…...................

Schoellhorn (1999) discusses three mechaisms which allow one to react adequately and rapidly to continuously changing situations in spite of their being unfamiliar:

-interpolation
-extrapolation
-peripheral self-organization

The principle of interpolation describes a process which estimates the region between two given states or conditions (already executed movements), while the principle of extrapolation is understood as the approximate determination of function values outside an interval on the basis of knowledge of values within the interval.

Because of the uniqueness of a movement a difference to the previous and following realization arises every execution. If a movement is executed three times, the third movement will lie either in the area between (interpolation) or outside (extrapolation) the difference spanned through the first two movements.

In Schoellhorn's words (1999), the phenomenon of extrapolation is largely unexplored, in contrast to the mechanism of interpolation, where numerous models of artificial neuron nets/webs are available which have been applied successfully.

Artificial neuron nets/webs (KNN [kuenstlice neuronale Netze]) are oriented on function models of neurons they are information processing systems which consist of a large number of simple units (cells, neurons) and which send themselves information in the form of activation of the cells via directed connections (Lindenmair, 1995; Schikuta, 2003) Artificial neuron nets are characterized by their ability to generalize; this is understood as the property of the net, through *training,* to classify unfamiliar data successfully. It is a remarkable insight that previous models produced better results using interpolation of certain data than extrapolation. In order to extend the applicability of such a neuron net, the attempt is being made to use besides the number above all the area of training data as broadly as possible. (cf. Schikuta, 2003; Schoellhorn, 2003)

The third principle introduced by Schoellhorn, peripheral self-organization, displays numerous parallels to Bernstein's work. This has to do with the problems of a central movement programming in the process of simultaneous modification of the movements execution. If a comprehensive detailed program of all movement elements over the total course of the execution is there – as if propagated in strictly hierarchical open-loop models – then the question arises how in spite of that it is possible to react to unfamiliar/unknown disruption and influence quantities as quickly and adequately as possible.

To solve this dilemma Schoellhorn proposes (1999) to grant qualities to the movement elements taking part at the periphery which have on their own supporting influence on a somewhat more broadly grasped target movement.

Bernstein had already (1975) formulated how in the idea of functional ambiguity of the connection between motor center and motor periphery the "motor effect of the central impulse cannot be decided in advance in the center," and thus a complete prior programming cannot explain the sequence of events at the body's periphery.

On the basis of the movement of generating forces, which are not called forth by the contraction of the muscles, such as gravity and resistance forces, there exists no clear dependency between central impulse and movement, that is, one and the same sequence of forces can engender different movements during sequential repetitions. The connection, according to Bernstein (1975), is the smaller the more complex the cinematic chain set in motion.

Movements are only possible if a very subtle, continuous, unforeseeable agreement of the central impulse with the *external field of force* takes place.

As an example that this agreement organizes itself *on its own* at the periphery, Schoellhorn (1999) mentions a study by Wagner and Blickhan (1999) in which it was shown that the adjustment of certain muscle parameters is sufficient to keep a cyclical movement stable.

…....................

In the more recent concept of *muscle tuning* by Nigg (1997, 2003) the vibrations of impact forces effecting the body are dampened by the self-regulating change of *muscle-stiffnes*s. Loeb (1995, cit.in Schoellhorn, 1995) calls the predisposition of the movement system to react quickly and adequately to new situations *preflex*. This mechanism, which operates without higher level control authority of the central nervous system, can " be viewed as the continuous anticipation (interpolation) of the furture on the basis of previous conditions, or as a short-term expectation-attitude with reference to what is coming, and serves the most rapid possible reaction to the newly encountered situation.

5.2.3.Practical-Methodological Teaching and Learning Principles

According to Schoellhorn (1993, 2003), differential learning and teaching represents one of the few attempts to unify the knowledge gained through system-dynamic analyses in the area of movement learning in a methodological concept. Nevertheless the postulated approach is limited to a few though essential principles and encompasses muc more a collection of exercises than a stringent method-concept, in which case we would point out that a strictly linear methodology, as it is described by classical models and which the practitioner is wholely accustomed to, contradicts the non-linear character of self-organizing systems, or at least would not do it justice.

Following the variations which appear in biological adaptation processes, the skill for inter- and extrapolation are to be improved through the introduction of differential exercises as also peripheral self-organization processes are supported.

To further the advance of self-organization the variations during the familiarization and automatizing processes are purposely emphasized by means of the most many-sided (differential) movement tasks. Along side of that the athlete is afforded the possibility to seek out for himself from the number of exercises those which seem to him, consciously or unconsciously, to most sensible with respect to movement economy and relevance to learning.

The leading points discussed by Schoellhorn (1999) for the manner of proceeding with differential learning are oriented on the Gestalt-theoretical principles of perception and correspond to those three metric and topological category markers which were put forth for the system-dynamic consideration of the complex discus throw movement:

-varying the beginning and end conditions
-changing the range of characteristics
-exchanging the course of the movement in duration and rhythm

The variations of the beginning conditions includes, for example, walking with bent and stretched knee joints, whereas walking with longer and shorter steps, rapid or slow, would primarily come under the range of characteristics. The change of movements style – springing, creeping, walking – corresponds to the modification of the course of movement and thus to the third category of differentiation.

In Schoellhorn's words, the change in possibilities in general can be applied to every joint by varying

-joint angle
-joint angle speed
-joint angle acceleration

In systematizing the learning process in the beginning primarily the angle (geometry) is changed, whereas with the advanced staged of learning increasingly differences in the area of angle speed and later in the area of acceleration(rhythm) are inserted. The sequence may only be understood as a principle of accentuation, for Schoellhorn recommends that variations in all three areas be done, in every stage of learning.

The suggested variation possibilities for sprint and running instruction encompass the already cited metric and topological as well as cinematic feature categories, where the partitioning of the potential modification parameters as well as the nomenclature is differently chosen and expanded through the variation of psychological processes in the form of selective steering of the attention (Schoellhorn, 2003):

-spatial aspect
  -range of motion of the joints
  -side of the body: left/right
  -extremities:arms/legs

-space-time aspect (velocity)

-dynamic aspect (acceleration)

-timing aspect (rhythm)

-steering the attention to specific areas of the movement

Simon et al. (2003) fills out the categories promoted by Schoellhorn with the muscular dimension. By way of the variations of muscle tension – cramped or loosely executed movements – the interplay inherent in every movement skill between tension and relaxation, that is to say the most rapid and situation-appropriate adaptation of the muscle tension, is to be supported. If one sees the muscle as a spring and the muscle tension as spring constant (C=mw2), the moving in the resonance freuqnecy with the muscle in the sense of utilizing reactive forces can contribute to the movement economy (ex.optimal step frequency). (cf. Dalleau, 1995; cit. In Simon, 2003)

Besides the fundamental variation possibilities of the movement task, Simon et al. Suggest varying the manner of execution within the movement task in addition. With that in mind the following forms are differentiated:

-constant conditions
-switching conditions
-adding and subtracting variation

While the first intends holding the type of variation constant (ex. Walking with extended elbows), the switching/shifting variation aims to execute two or more variations changing back and forth (ex.walking with bent and stretched arms alternately each five steps). In the last execution modality the variations within the movement assignment are increasingly elevated or reduced (ex.walking with bent elbows and then stretching them more and more).

…........................

[Motorik 421].... the intentional execution of *movement mistakes* in order to strengthen the learning-relevant (necessary) deviations.

…....................

…..*feeling out* of the different impulse forces

…..................

[M 422] ….in order to destabilize a *falsely* automatized gait pattern and to find for each individual an optimal scope of function.

As is postulated in ecological and control steering models, movement activities always stand in direct relationship to perception (*perception-action coupling*) and are thus fundamentally influenced by environmental conditions – so-called constraints. Schoellhorn suggests inserting such determinants of movement intentionally, so that differences can be achieved which are otherwise hardly to be realized.

An efficient, if drastic, example is the differentiation of the internal dynamics of going over the hurdles. Hurdles arranged in a curved shape serve as constraints; because the longer path on the outside of the curve the athlete is forced to bring the trailing leg more quickly forward (if not the hurdle will do the rest, so that the runner elevates the dynamics in the next attempt).

Transferred to the chosen example of walking down a mountain, such constraints as marks on the ground could be used to achieve certain differences in step length. With acoustic information, ex. Eternal tone signals (clapping) in varying rhythms, the differences in the movement dynamics can be more easily achieved (Schoellhorn, 2003). With forward lean of the upper body turning the lower arms outward helps, or with leaning back tippig the head forward, thus correcting the body posture *forceably* (Schoellhorn, 2003).

[example of sprinters: differentially trained group improved more, retention of learning in shot putters was longer, and continued improvement]

[Motorik 428] It is no circumstance that Nicolai A. Bernstein is described as the pioneer and father of system-dynamic motor movement research. He recognized (1975), long before chaos theory and synergetics began their uncontested victory course, that the not-to-be-influenced dynamic of the surroundings/environment stand in *decisive contradiction "to any sort of available possibility of imprinting the brain with standardized motor formulas. One might add that in undertaking to work out a new skill taking such a path could not lead to anything other than that a beginner would take on awkward, false movements*."

Through this recognition Bernstein (1975) came to the insight that the constant repetition of an exercise cannot be part of the learning process, for which he formulated his since then oft quoted postulate: *Exercise is repetition without repeating!* For at a point where there is development every subsequent execution is better than the previous, that is, there is no real repetition. That holds true for skill development as well.

For Bernstein the resolution of the apparent paradox lies in the understanding that the correctly executed exercise does not repeat the means but the process of solving the relevant movement task; the means, however, are from time to time changed and amplified. For the real essence of the exercise process toward mastering a new movement consists of gradually seeking out optimal movement procedures for responding to the task to be internalized.

For every human being there exists for each movement task and based upon the biomechanics of the body build only one dynamically stable from through which the subject has learned to utilize reactive forces optimally. "With respect to sports and track movements these dynamically stable forms approximate what we call *movement style*." (Bernstein, 1975)

Agreein with Bernstein, Fidelius (1997) demands that each athlete stamp his own style, his totally individual manner of getting to his movement goal. "The master cannot be repeated." For only the brain of the athlete is capable of making optimal decisions about how details are to be observed.

Table 17. Contrasting of Information Processing Theoretical View and Dynamic System View of Movement Control and Steering.

Divergence Criteria	Motor Approach	Action Approach
alternative names	information processing approach cognitive approach representation approach computer analogy approach program approach cybernetic approach cinematic approach	system dynamic approach ecological approach ecological-dynamic approach self-organization theory dynamic system theory action theory
guiding principle	man-machine metaphor	self-organization
origin in psychology	cognitive psychology	Gestalt psychology ecological perception psychology ecological realism
origins in natural science	computer science engineering science	chaos theory synergetics connectionism
entry into motor studies	end of the 50's	end of the 70's
movement organization	alien organization through action programs	self organization through coordinative structures
causality principle	linear causality	non-linear (circular) causality
manner of observation	element-synthetic (structural)	whole form-analytic (phenomenological)
control model	hierarchical: top-down	heterarchical: bottom-up
information processing	serial-local	parallel-distributed
man-environment relation	implicit man-environment dualism (person-centered)	explicit man-environment synergy
perception	indirect (provided) perception through filter and calculation processes	direct perception
link between perception and movement	separation of perception and movement: the perception which precedes action is interpreted as an independent serial process.	unity of perception and action in simultaneous regulation of movement: "We must perceive in order to move, And we must move in order to perceive."

deviations	purely stochastic (random, conjectural) indirect influence on system behavior	system-inherent-stochastic & determinist direct influence on system behavior
representation structures	necessary to translate abstract program into muscle commands	not necessary because of peripheral self-organization
intention	serves in choosing the motor program	operates as a constraint in the sense of an attractor
function of the muscles	carry out the centrally represented control commands	take part in the movement-organization as a subsystem (but not absolutely necessary)
research paradigm	experimental design oriented on classical physics	identification and analysis of collective variables with the aid of complex, non-linear procedures
investigated forms of movement	primarily acyclical	primarily cyclical, continuous

Table 18. Motor Learning: Contrasting Information Processing Approach to System-Dynamic Approach.

Divergence Criteria	Motor Approach	Action Approach
learning model	scheme theory learning theory of Adams steps theory	system dynamic learning theory differential learning
guiding principle	learning as improved information processing-strategy and development of heightened processing capacity	learning as the development of abstract (phase-) relations (order parameters between the system components and their interaction with the environment
learning principles	program learning, motor-sensory learning, scheme-, model learning	interpolation, extrapolation, peripheral self-organization
mode of invariants	established a priori	learned a posteriori
variations/fluctuations	mainly avoided	relevant (necessary) for learning
memory	basis for improving strategy education and long-term skill acquisition	little meaning for learning, since memory processes presume internal representations
movement experience	ascribed to memory in the form of representations	determine the intrinsic situation-dynamic as internal constraints
research paradigm	product-oriented, time-discreet analyses, (changes in movement results)	process-oriented, continuous time analyses (changes in order/form parameters)
investigated movement forms	primarily acyclical	primarily cyclical, continuous

Table 19 Consequences for Motor Learning and Teaching

Divergence Criteria	Motor Approach	Action Approach
teaching method	prescriptive	interpretive
emphasis	new learning generality/for all	learn anew individuality
practice techniques	constant practice of: consistent total picture, consistent position, consistent result. variable practice: randomized, block, serial learning	differential practice in the presence of the whole area of possible variations, deviations.
goal technique	technique model image	individual ideal technique
technique training	automatization of a previously constructed model image	search of the optimal function space for the solution to a movement task
variations/deviations	to be avoided in skill acquisition	to be purpousfully employed at every skill level
variability/difference	instructed variability in practice	results-defined individual differences
variation modalities	variation of parameters and program	metric and topological features of differentiation
variation:how shown	increases with rising skill level	decreases with rising skill level
prior experience	remains largely unconsidered	connecting point for the learning process
awareness/consciousness	learning through insight	largely implicit
didactic limitation	the structure of the generalized motor program may not be altered	the uniform perception-action structure may not be altered