Problems of coordination in swimming: a motor learning approach

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ABSTRACT

WILKE K. Problems of coordination in swimming: a motor learning approach. Kinesiology, Vol. 2. No. 1, pp. 9-18, 1997. The refinement processes nt the movement regulation (motor control) is considered to he a larger inner reserve than the domain of conditioning. In sports the refinement concerns two essentials of movements motor skills and coordination abilities. A motor skill like the technique of backstroke of no-touch-turn is defined as the result of exercising, which didactically differs from motor learning and conditioning. The characteristics of a skill are economy, constancy and stability. Problems of skilling arise from isolated and slackened exercises as well as from cluttered repetitions. A methodology to avoid these problems is explained. Physical changes, together with the necessity for stroke corrections, for the adaptation to new rules and to the nascent swimming speed, renders it necessary to maintain continuously appropriate coordination adjustments. A motor coordination ability is the sensori motor prerequisite for a whole category of movements; it contains the transferable structures of these movements. In order to improve coordination abilities one approach deals with the training of motor analysers, another with the training of motor commands. Even an elite swimmer will rarely reach the perfection of his defferentiation ability for a longer period. New tasks, conditions, situations have to challenge permanently the sensorymotor system in order to adjust the mastered skills.

Key words: EFFICIENCY OF MOVEMENT, MOTOR CONTROL, MOTOR SKILLS, COORDINATION ABILITIES, SWIMMING TECHNIQUES, DIFFERENTIATION ABILITY

Since the eighties movement technique has become an important factor of swimming performance. Actually the refinement of motor control in sports is generally considered as the larger inner reserve than the domain of physical conditioning. Improved motor control can increase the efficiency of the movement process, i.e. the same energy expenditure produces a higher locomotion velocity or the same velocity needs less energy (measured through physiological parameters). This is surely relevant to swimming because the water resistance increases squarely with the accelerated speed of the swimmer's body. So any deviation from the biomechanical optimum or any stroke error inadequacy will affect the athlete's overall performance. Additionally the charge of one small deviation will be multiplied by the quantity of movement repetitions per distance. This could result in a gross deficiency when swimming a race. According to this knowledge the process of acquiring a particular swimming technique consists of different stages of motor learning and exercising. The stages differ from each other, especially concerning the psychological and didactical conditions.

"Coordination of movement is the organisation of motor actions towards a definite goal or purpose" (Meninel/ Schnaberl 1987). It represents only one of the most important psycho-physical components which form the capacity of motor acts (Figure 1). The componenets of the coordination in competitive sports, which have to be refined, are the following: motor skills, coordination abilities, sport type related motor skills, sport type related coordination abilities, movement schemes and combination of sports type related coordination abilities.



Figure 1. Structure of the individual capacity of motor acts: Four components (HIRTZ 1994).

As theoretical frame can be regarded the model of the Inner Representation of intended movements (Bernstein 1967), the Sensori/Motor Theory (Ungerer, Schnabel, Fleiß 1977-1987), the Schema Theory (Scmidt 1975-1991) and the model of Coordination (Hirtz 1994). The following presentation will focus on two motor components which form the crucial points within the progressive formation of an elite swimmer: motor skills and coordination abilities.

Swimming technique and skills. "A skill is understood as a largely automatically executed component of conscious human activity, which is mainly developed through practice (Beyer 1987). The skill as a goal directs arbitrary motor action progresses during the process of exercising which is linked with descending levels of regulation within the central nervous system (Figure 2). "Since the execution is largely automatic, consciousness does not constantly direct the process. The process of automation and stabilisation is initially dependent on consciousness during the acquisition stages but not so during mastery of skills, when the process is capable of being conscious" (Beyer 1987). When a skill is related to concrete movement as to breast stroke swimming or to the no-touch-turn, it is specified as a motor skill. Motor skills can be regarded as relatively automatical components of a sportive action. They are linked with processes of sensation and self-regulation. Each skill contains a particular spatial and temporal pattern. To improve the swimming skills means to increase their economy, constancy, stability against disturbances, i.e. against fatigue, stress, lack of concentration or irritation by the anticipation of the race.



Figure 2. Model of regulation levels during the process of motor learning (QUITSCH 1989).

The most effective method to form skills out of the learned movements consists of different facilitations of the normal executions. At the beginning of practising the swimmers need their consciousness in order to execute proper component drills as well as to integrate them. Offer comfortable conditions of practising not too fast, not too hard, not too dense, but with appropriate rest intervals. Although facilitating the normal execution of the swimming technique forms the core of skilling, we must be careful to perfect the stroke, not a drill. If we practice the isolated stroke drill too often, we endanger the amount of positive transfer of the drilling component to the full stroke, e.g. the rhythm of leg kick by hundreds ot meters differs structurally from the kick within the full stroke. So we integrate the practised characteristic directly afterwards into the full stroke. Thus, the initially leading cognitive images of the correct movement are shifting gradually to bodily feelings, better said to somatic perceptions. For this reason the external conditions may change a little and stimulate the somatic perception. Though at first the concentration on a particular characteristic may be facilitated by a slower movement at first, the final execution should be repeated in the actual speed. In the course of time the practised movement will be regulated by lower parts of the nervous system, i.e. without permanent awareness.

While mastering this process the motor nervous system shows a low fatigue limit. Therefore, only one swimming technique at most two

techniques per practice unit provide appropriate conditions to improve the skill. The motor nervous system needs many repetitions for shifting from conscious control to the automatical regulation of the movement. Therefore, it should not be overstressed by many different demands. For the same reason a dissemination of the same exercises shows better results than a cumulative practice. If the same movements, the same nervous connection, the same motor control are stressed too often and too densely, the result will diminish.

That means: the same technique and the same exercise should not be performed longer than 10-15 minutes and not more than twice per week.

Contribution of coordination abilities. "The control of movement must be tuned to the varying characteristics of the body. This situation, together with the necessity for the further development of speed and coordination, renders it necessary to maintain continuously appropriate coordination adjustments in the programme of controlled physical development. This means that the mastery of new movement patterns should have a permanent place in the sports coaching programme" (Israel/Buhl 1980, 196).

So the main reasons for the long-term movement formation are caused by the dependence on:

• the changes of the human body (=human natural development).

• the changes of the human capacities, i.e. strength, endurance, flexibility, as they are influenced to a large extent by conditioning (=socially influenced human development).

It is imperative to bear in mind the necessity for the adaptation of swimming techniques because of the following:

- the stroke corrections.
- the modification of the competition rules.
- the prevention of speed barriers as illustrated in Figure 3.





The quality of technique adaptation and the success of learning new techniques also depend on the existence and further development of coordination abilities. A motor coordination ability is the prerequisite for a whole category of sportive actions. It controls a family of similarly structured movements and contains transferable structures of these movements. It depends strongly on permanent feedback of the exteroceptive perception and especially of the enteroceptive perception, which means the reafferentiation from skin, limbs, muscles and tendons (Figure 4).



Figure 4. Sensori-motor Circle: (WILKE 1990).

In terms of sport science, abilities are defined as learned or inherited psycho-physical qualities needed for the achievement of a certain performance. Coordination abilities overlap the motor skills: They use them as a kind of disposable elements, like the artisans use prefabricated products to build a normal house. Therefore, the semantics say "the ability for something" instead of "of something". They often are devided into so-called primary abilities-belonging to the genetic equipment- and acquired abilities by learning. Primary and acquired abilities can be combined. Thus, we are able to develop abilities. We do this by applying as many motor skills as there are at our disposal in order to elicit the maximum of the concerning coordination abilities. Accordingly, the motor formation in swimming altoghether shows a kind of dialectical model where the swimming skills represent thesis, and the abilities related to swimming represent the antithesis (Figure 5). Synthesis of both composes the next higher level, which provides the base to enlarge the amount of skills. These new skills on the other hand form the tools, which must be applied in order to refine the coordination abilities.



Figure 5. Dialectical model of motor development and formation.

Relevant coordination abilities in swimming. In swimming the most effective coordination abilities are the orientation ability, coupling ability, reaction ability, rhythm ability, differentiation ability and switch-over ability (this only for the individual medley). Human abilities never operate separately but cooperate with other abilities. During cooperation they also

interact, i.e. influence each other. Therefore, practice should always focus on one of the coordination abilities in order to direct a concerning stimulus to this particular ability.

The *COUPLING ABILITY* can be considered as a basic ability of motor coordination:

• as simultaneous interconnection of movements of different limbs to each other, of trunk and limbs, of head and trunk respectively, e.g. the simultaneous entering of left hand and kick of right foot in two-beat crawl.

• as synchronization of different muscles (e.g. agonists and antagonists), i.e. as an aspect of intermuscular coordination, e.g. the relaxation of musculus triceps during initial arm pull by musculus biceps.

• as the transfer of momentum of partial body movements to the entire body, e.g. the transfer of armswing to the trunk, i.e. to the whole body during backstroke start.

• as a temporal shift in the onset of movement phases, e.g. the shift of dolphin impulse from the thigh, to the shank and to the foot kick.

The ORIENTATION ABILITY is the perception of one's own body position and its locomotion in space. It includes the distance to the pool wall as well as to another person. Its vestibular analyzer is always troubled by the horizontal head position and the involved postural reflex (Figure 6).



Figure 6. Difference of the orientation between human beings and animals.

The *RHYTHM ABILITY* arranges the appropriate perception and reproduction of one's own movement or those of other persons into periods, series of repetitions and it accentuates their dynamics. Its perception is based on kinesthetic, tactile, vestibular, visual and acoustic information.

The *REACTION ABILITY* in swimming means the complex reaction to move the whole body immediately after a signal in the shortest possible time.

Orientation, rhythm and reaction abilities depend to a large extent on the sensitiveness of their corresponding analyzers. Thus the training of analyzers is the key to their refinement (Table 1).

able 1. Iraining of analyzers of the aquatic orientation, reaction, rhythm abilities.			
ABILITIES	SENSORIUM	EXEMPLARY IMPLEMENTS	
Orientation	– visual – vestibular – tactile	The swimmer should define his loca- lization/locomotion swimming with closed eyes, blackened goggles - straight on, to the right or left - in a current of turbulence - passively moved, rolled, turned, twisted	
Reaction	– acoustic – visual – tactile	The swimmer should answer or tap with one finger as fast as possible after - a single signal (acoustic, visual, tactile) - one of two potential signals - one out of several signals	
Rhythm	– acoustic – kinesthetic – visual – tactile	He/she has to clap or say the thythm of a movement that – he/she is/was swimming just before – another person is swimming – different persons are swimming	

The *DIFFERENTIATION ABILITY* depends on the perception of space, time and muscle tension in one's own movements by means of receptors, sensitive to movement. The receptors belong to the exteroceptive and the proprioceptive analyzers: ears, eyes, skin, hair, labyrinth of the inner ear.

The leading receptor utilizes an extensive system within the tendons, muscles, ligaments and joints: the kinesthetic perception. In swimming it always interacts with the tactile analyzer of the palms, the skin of the limbs and the trunk. The differentiation ability is considered to be most important for elite swimming and depends extremely on the quality of the abilities mentioned before. It is better known as "feel for water" (Figure 7).



Figure 7. Feel for water and its positive characteristics (SCHUCK 1990).

Especially the subtle perception of strength, spatial and temporal relationship in speed and power, i.e. the changing cyclic movements, can be traced back to the quality of the differentiation ability. Examples in swimming are:

• Perception of space = angle of elbow joint; length of a pull, distance per stroke.

• Perception of time = speed of a movement, e.g. arm pull by means of muscle tension and tactile pressure: Thus it controls indirectly the stroke frequency.

• Perception of muscle tension for executed muscular force: It regulates the types and the amount of contracting muscle fibres, which is an aspect of intramuscular coordination.

The perception of muscle tension combined with the tactile sense form the crucial point of the controlling and feedback function of the differentiation ability in swimming. Accordingly, the method of refinement has to intervene here. Even an elite athlete's differentiation ability never stays in a perfect state if it was finally reached -i.e. even after years of practice. Nevertheless, each top swimmer loses his/her level of differentiation ability during phases of inactivity and periods of so-called log-training, e.g. extensively massed strength training.

Limitation of coordination abilities. At the moment it is still unknown if augmented coordination abilities enable to modify the swimming technique economically from 50 to 1500 m. Some results of research indicate that the highest degree of swimming economy needs the acquirement of discrete movement schemes even in the same technique (Figure 8). The different durations of armstroke phases in 100 and 200m (Rouard/Schleihauf/Troup 1994) as well as significant differences of the relative hand speed at the beginning and the end of 50m races (Langnickel/Wilke/Wirtz 1995) show that the relative timing in swimming seems to be no invariant (Figure 9).



Figure 8. Duration of swimming phases in 100 and 200m crawl. P1 = hand entering the water till an angle arm-trunk of 30°. P2 = 30° - 90°. P3 = 90° - 150°. P4 = 150° till the hand leaving the water. P5 = air phase. (ROUARD, SCHLEIHAUF, TROUP 1994).

However, the invariances of the sequencing, of the relative forces and the relative timing form the preconditions of a movement scheme according to the GMP-Theory (=Generalized Motor Programmes; Schmidt 1975). So, actually there is a tendency to enlarge the effectiveness of the coordinaton abilities, particularly of the differentiation ability. This means to stimulate their potential adaptation or the extent of the coordination variability by complicating the executions, modifying the situations and conditions and by directing and refining the sensory feedback. A last survey enclosed compares

the essentials of the motor skills and coordination abilities stressing the methodological differences of the motor learning approach (Table 2).

Figure 9. Curves of the relative wrist velocity at the beginning and the end of 50m freestyle sprint: Grapes of the left arm of the fastest swimmer (No. 1, A = at the beginning, \underline{B} = at the end) and the slowest swimmer (No. 10, C = at the beginning, D = at the end) (LANGNICKEL/WILKE/WIRTZ 1995).



	MOTOR SKILL	COORDINATION ABILITY
CRITERION	Automatical Components	Generalized Transferable Process
	of a defined Sportive	Qualities of Movement Control
	Technique (Action)	and Regulation
AIM	Perfection (Economy,	Prevention of Motor Stereotype:
	Constancy, Stability) of	Promotion of Coord. Plasticity
	a Particular Movement	
METHOD	Practising the None-Perfect	Varying Application of Completely
	Movement/Technique as a	Mastered Skills or Combining
	Whole and in Parts	Parts of the Skills
	(Whole-part-Whole-Method)	
CONTENTS	1 Technique per Training	4 Techniques per Training Unit
	Unit (at the Most: 2	(at Least: 3 Techniques/
	Techniques)	Combinations)
CONDITIONS	Demands as is Customary	Novel, unusual (at Least Partly
		Novel) Demands
AMOUNT	Many Repetitions per Unit	A few Repetitions per Unit
	(at Least: Threefold Amount	(at the Most: One Third of Skill
	of Ability Exercises)	Exercises)

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