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The manner of research into psychomotor transfer in sport on the basis of learning process analysis

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The presented manner of investigating transfer was illustrated on the basis of research into 12 senior and 10 junior members of the Polish male national table tennis team, 6 highly skilled, adult, female table tennis players, 23 children practising table tennis, 13 highly-skilled male tennis players, and 9 adult, male competitors, highly skilled in other, non-racket sports. The term *psychomotor learning* was introduced. This learning was divided into movement, skills and situation motor behaviour. The research depended on the multiple repetition of a series of 17 simulated ball hitting movements and measuring the speed of these movements. The results were approximated by an exponential curve. Transfer was examined on the basis of the speed and range of learning calculated with respect to learning curves. The ratio of these two magnitudes was treated as the index of transfer. This reflected the transfer of the anticipatory experience and motor skills learned in real table tennis play to the conditions of simulated play. The index of transfer was the highest among female seniors and children, lower among male seniors and juniors practising table tennis and tennis, and the lowest among the group representing other sports. The research demonstrated the greater flexibility of anticipatory schemas and ball hitting skills in the group of female seniors and children than among the male seniors and juniors. The lowest transfer occurred in the group of other sports because of the small number of anticipatory and motor skills useful in table tennis play.

Key words: transfer, learning curves, the manner of research, simulator, table tennis, index of transfer

1. Introduction

Motor learning consists in performing movements in order to acquire the ability to recall these movements and to achieve a desired result (SCHMIDT [7]). The whole process is described by learning curves (BAHRICK, FITTS and BRIGGS [1]), which are usually exponential (WOODWORTH and SCHLOSBERG [10]) and can be divided into movement, skill and situation motor behaviour learning curves. These curves are often called *performance curves* (SCHMIDT [6], FLEISHMAN and RICH). The essence of the meaning of the term *performance curves* is closer to the term *movement learning curves* than to *skill learning curves*. In the previous approach, the performance curves should have been divided into movement performance and efficiency curves. Nevertheless, both of these terms can still be very useful in describing the process of transfer.

The movement learning curves describe graphically the extent to which movement learning coincides with its model during the learning process. Motor skills can be treated as movements which enable achieving a desired result of these movements. The skill learning curves thus describe the extent to which the result of skill learning coincides with its goal. Movement learning is the first stage in a properly run learning process. The latter stage in this process is the learning of a skill: how to achieve a chosen goal in definite situations with the aid of a particular movement. In many sports, the situation offers a choice of different goals and types of motor behaviour on the part of the subject. This kind of human behaviour has been called *situation motor behaviour* (ŁAPSZO [2]), which requires recognition of the situation, decision making, movement programming, and its execution. The learning of such behaviours constitutes the third stage of human motor behaviour. This process consists in improving those human capacities that allow the subject to assess a situation very quickly, take a correct decision, and modify a learned movement in order to achieve the desired result. The ability to achieve different goals by the application of different skills in different situations has been called the *efficiency* (STELMACH [8]) of a human being in situation motor behaviours. During all three separate stages (movement, skill, situation behaviour learning), motor learning is of a psychomotor nature, that is, it requires the involvement of both the psychic and the motor spheres. With respect to this, movement, skill and situation behaviour learning can be treated as *psychomotor learning*, while the curve describing these processes can be called the *psychomotor learning curve*; furthermore, human efficiency in situation motor behaviours has the nature of *psychomotor efficiency*.

The proposed manner of investigating the transfer on the basis of learning curves takes into consideration all three kinds of psychomotor learning. In this paper, this manner will be illustrated on the basis of situation motor behaviour learning curves. These show the increase in psychomotor efficiency during the learning process.

The learning process of situation motor behaviours can be investigated holistically or analytically. The holistic approach involves the measurement of a single factor, which is influenced by various abilities and skills and express the level of psychomotor efficiency (for example, the score in a tennis match). In the analytical research, a number of selected factors are measured separately. The holistic factor can be treated as an index of human psychomotor efficiency, which in many sports depends on the speed, suitability and precision of situation motor behaviour. The graphical presentation of this holistic factor during psychomotor learning (learning of situation motor behaviours) can also be called the *curve of psychomotor efficiency improvement*. These curves describe the changes in psychomotor efficiency as a result of learning. The movement or skill learning curves represent the analytical way of researching psychomotor learning. These factors constitute particular components of human psychomotor efficiency which, when investigated with respect to a given sport, can be referred to as specific psychomotor efficiency factors.

This paper introduces the manner of investigating transfer in improving psychomotor efficiency during simulated table tennis play. This method is illustrated on the basis of research on competitors representing table tennis, tennis and other sports. Table tennis is very popular and most of us have the opportunity to play it. In this respect, the psychomotor learning process is a kind of transfer. In human motor behaviour, transfer can be treated as the increasing (positive transfer) or diminishing (negative transfer) ability to perform definite motor activities as a result of one's ability and experience in performing other activities (SCHMIDT [6]). In the present paper, *transfer* is defined as the influence – positive or negative – of earlier psychomotor experiences (psychomotor capacities and learned skills developed earlier) on the situation motor behaviour being learned now. The aim of the present research was to investigate the transfer of psychomotor experience acquired in real table tennis play to simulated play. This transfer was examined on the basis of psychomotor efficiency improvement curves, so this transfer can be called *psychomotor transfer*.

2. Subjects and the research method

Research into the following groups of subjects are presented in the paper: 12 senior and 10 junior members of the Polish male national table tennis team; 6 highly-skilled, adult, female table tennis (t-t) players; 23 children with an average age of 11.2 years and with 2.25 years of special training in table tennis; 13 highly-skilled male tennis players; 9 adult, male competitors, highly skilled in other, non-racket sports (football, volleyball and dancing).

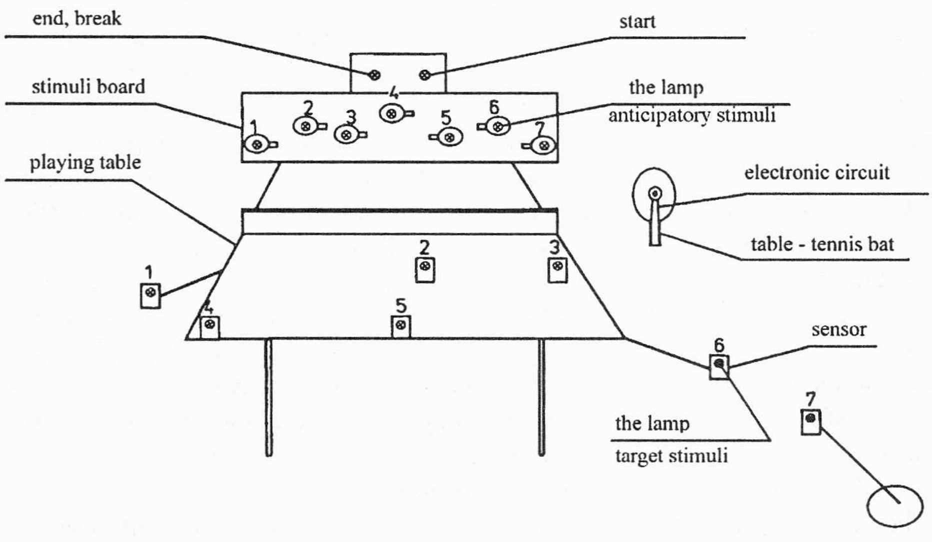

Fig. 1. The table tennis play simulator

The table tennis play simulator was used in the research (ŁAPSZO and MORAWSKI [5], ŁAPSZO [4]). The simulator consists of a measuring station, controller and computer. The measuring station consists of a stimuli board, a set of sensors and a special table tennis bat (figure 1). The simulator enables 7 ball hitting movements typical of table tennis to be investigated. The simulated strokes of ball were stimulated by 7 lamps located on the stimuli board. Each of these lamps was associated in the computer programme with a definite lamp in the sensor. In this way, 7 constant pairs of lamps were created, which constituted the *simulated anticipatory schema*. The schema reflected the predicted placing of the ball by an opponent from given locations at the table. Both lamps were switched on sequentially to simulate the ball's flight. The lamps on the board simulated the place where the ball was struck by the opponent. The lamps in the sensors indicated the spot where the required simulated stroke had to be performed by the subject. These simulated forehand and backhand strokes involve the flexible straps placed in each sensor being hit with the special table tennis bat. These flexible straps require the hits to be performed with a certain precision and with the table tennis bat at a given angle of slant at the moment of contact. The simulated hitting of t(**2000**) he ball is registered photoelectrically, so the strokes can be performed at top speed. The time (in seconds) elapsing from switching on the lamp on the stimuli board to the instant of simulating the hitting of the ball was the measure of the speed of tested movements. The result of the measurements was the average speed of a series of 17 simulated ball hitting movements.

Psychomotor transfer was investigated on the basis of the learning curve of simulated table tennis play. The learning process involved learning anticipatory schema and simulated ball hitting movements. The motor and anticipatory skills applied in real play were transferred to simulated play. The transfer of motor skills as applied to the ball hitting and displacing skills consists in the adaptation of these skills, learned under natural conditions, to the simulated conditions. The construction of sensors elicited this modification (a particular angle of slant of the table tennis bat). Achievement of the simulated ball hitting skill was indicated by the lamp in the sensor switching off and by an audio signal at the instant the elastic straps were correctly struck. The anticipatory skills consist in the memorisation of a lasting relationship between the various spots towards which the ball is hit by opponents, the line of ball flights and displacement movements of the subject to these places. These skills are apparent at the initiation of the displacement movement already at the instant the ball is struck by the opponent or during the initial phase of the ball's flight. The application of anticipatory experiences from the real to simulated play constitutes the essence of the transfer of anticipatory skills, and is apparent at the initiation of the error-free displacement movement to the appropriate sensor already on the basis of the lamps on the stimuli board (early anticipatory information).

The curve of simulated play learning was used in this research into transfer. An example of the learning curve is shown in figure 2. The simulated ball hitting movements (series of 17 strokes) were tested until the results stabilised, but no more than

12 times. The changes in the speed of this test during the learning process describes the improvement (irregular increase) in psychomotor efficiency in simulated table tennis play. The results of measurements were approximated by the following exponential learning curve:

$$T(n) = (T_{\max} - T_p) \times (1 - S_l)^{(n-1)} + T_p, \tag{1}$$

where: n – serial number of the trial, $T(n)$ – the result of the test as a function of the trial [s], $T_{\max}$ – the lowest speed of anticipatory sequential movements (the longest time) [s], S_l – the speed of learning (increase in psychomotor learning in each trial, computed), T_p – potential speed [s] (the asymptote of the learning curve, computed).

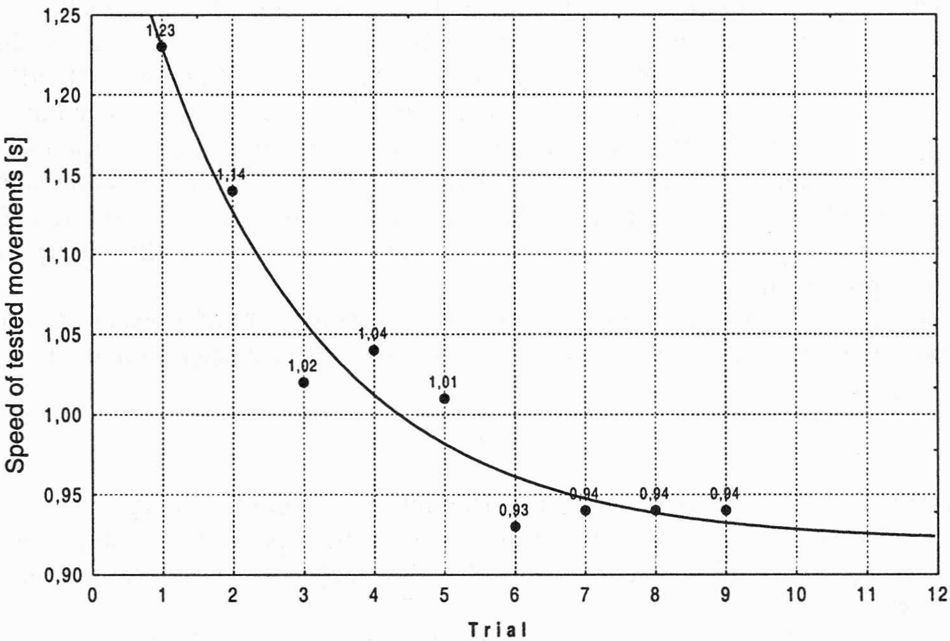

Fig. 2. An example of the learning curve

The speed of learning S_l is expressed as the fraction of the tested speed of movements increasing in each trial with respect to the asymptote of the learning curve, and can be presented as follows:

$$S_l = [T(n) - T(n+1)]/[T(n) - T_p]\,. \tag{2}$$

The greater the speed of learning, the faster the transfer of motor and anticipatory skills (learned in real play) to the simulated play (easier modification of the shape of ball hitting movements and faster learning of simulated anticipatory schema). The speed of learning can be treated as the *measure of speed of transfer*. The speed of transfer reflects the degree of flexibility of existing motor and anticipatory skills. The flexibility of learned skills is susceptible to modification. The greater speed of learning also indicates that the subject has learned more at the beginning and less during the later part of the learning process (the anticipatory schema were not memorized systematically in each trial).

The range of learning R_l was also investigated. It was calculated from the following formula:

$$R_l = T_f - T_l\,, \tag{3}$$

where: T_f – speed of tested movements in the first trial, T_l – the average speed for the last three trials.

The range of learning can be treated as the *measure of range of transfer*. The range of learning is connected with transfer, because it reflects the degree of similarity (the number of common elements; THORNDIKE and WOODWORTH [9]) of motor and anticipatory skills learned in real play with simulated strokes and anticipatory schema. The less the range of learning, the less a subject had to learn; that is, the less the extent to which the subject had to modify the motor and anticipatory skills learned in real play to achieve the stabilisation of results in the research. The range of learning probably also indicates the ability to memorise the anticipatory schema (good memory).

On the basis of the measurement of speed (S_l) and range (R_l) of learning suggested in this paper, the index of transfer is introduced. It can be calculated from the following formula:

$$I_t = S_l / R_l\,, \tag{4}$$

where: I_t – index of transfer, S_l – speed of learning, R_l – range of learning.

This index enables the magnitude of transfer to be expressed by a single figure with respect the speed and range of transfer. The higher the index, the greater the transfer.

The proposed manner of research can also be used to measure the general capacity of a human being to learn movement, skill and situation behaviours. In this case, the learning movements, skills and situation behaviours should be quite new for the subjects. Such a situation occurs very rarely, because every one of us has a given psychomotor experience (learned movements, motor and anticipatory skills, situation behaviours). This experience differentiates us. Transfer was defined as the influence of earlier experience on the learning process. Because everybody has their own set of psychomotor experiences, every kind of motor learning is probably of the transfer type. Where it is known that motor learning is based on earlier experience, it should be called *transfer*; in other cases, this process should continue to be called *motor learning*. When this method is applied in research into transfer or motor learning, the speed of learning will reflect the speed with which new or transferred psychomotor experience is acquired. On the other hand, the range of learning will describe the coincidence of possessed experience with the experience necessary to learn definite movement, skill or situation motor behaviours. In research into motor learning, the index ($I_t = S_l / R_l$), elaborated for measuring transfer, can be referred to as the *index of psychomotor learning capacity.*

3. Results and discussion

The results of this research, i.e. the average range (R_l), speed of psychomotor learning (S_l) and index of transfer (I_t), are shown in table 1.

Table 1. The average range (R_l) [s], speed of psychomotor learning (S_l) and index of transfer (I_t) for the groups tested

Tested groups	*N*	The range of learning (R_l) [s]		The speed of learning (S_l)		Index of transfer (I_t)	
		M	SD	M	SD	M	SD
Children t-t	23	0.34	0.10	0.33	0.22	1.13	1.05
Male juniors t-t	10	0.37	0.13	0.31	0.13	0.79	0.53
Female seniors t-t	6	0.3	0.16	0.4	0.16	1.71	1.11
Male seniors t-t	12	0.36	0.13	0.26	0.14	0.82	0.54
Tennis players	13	0.31	0.12	0.28	0.12	1.07	0.77
Other sports	9	0.37	0.15	0.23	0.06	0.7	0.29

M – mean value, SD – standard deviation.

The presented manner of research into transfer in psychomotor learning was successfully tested on the basis of investigations of table tennis players (ŁAPSZO [3]). The results have shown differences between groups practising the same sport with respect to age, sex and sporting skills. This research has also shown up the differences between groups practising different sports. Unfortunately not all these differences are statistically significant, so this problem will require further investigation. Statistically significant differences were found for:

- the range of learning between male juniors and other sports; tennis players and other sports,
- the speed of learning between children and male seniors, children and other sports; male juniors and tennis players; female seniors and male juniors, female seniors and male seniors, female seniors and other sports; male seniors and other sports,
- the index of transfer between children and male juniors, children and male seniors, children and other sports; female seniors and male juniors, female seniors and male seniors, female seniors and other sports; tennis players and other sports.

In order to demonstrate that the method is a useful way of examining the transfer of skills between similar sports, a group of tennis players was tested. The possibility of applying this method to the measurement of psychomotor learning capacities (not transfer) was examined on the basis of a study of a group of competitors practising other sports, who could treat the simulated ball hitting skills as earlier unknown skills (new skills). All these investigations are presented in this paper in order to show that:

• the essence of the method is the study of the learning curves, which can describe the conversion of one set of skills into another or the learning of new skills (not only motor skills),

• the method differentiated the groups representing the same sport, similar and different sports; however, it unfortunately did not do so with respect to all the factors examined and all the groups, probably because of the small size of the test groups.

The research indicates that the index of transfer (I_t) is a better discriminator of the groups than range (R_l) or speed of learning (S_l). The range of learning can be interpreted as the range of changes in the anticipatory schema memorised during earlier experience, and in the ball hitting skills applied in real table tennis play. The greatest range of learning was found among juniors and senior males, and the other sports. This implies that the simulated play required from these groups the greatest modifications of their existing anticipatory experience and ball hitting skills. Fewer modifications were recorded among senior females, tennis players and children.

The speed of learning can be treated as an index of the flexibility of existing anticipatory schemas and ball hitting skills. This index was the highest among senior females, children and tennis players, but the lowest among male juniors and male seniors. In the group of other sports, anticipatory and motor skills were found to be developed to only a slight extent.

With respect to the table tennis groups, these results show that the play of male juniors and male seniors is more predictable (more schematic) than that of women and children. Moreover, because the ball travels at high speed, the particular shapes of the ball hitting movements have to be fixed in the memory.

The index of transfer takes into consideration the range of the required changes of schemas and skills and the flexibility of the schemas and skills. The highest index of transfer was found among women, who modify their anticipatory schemas and skills with the greatest facility. The same applies to children and tennis players. The juniors and senior males encountered the greatest problems in transferring the existing anticipatory and movement skills to the requirements of simulated table tennis play. As far as the group of other sports is concerned, the psychomotor experience achieved by those who actually play them is small and therefore of little relevance as regards the transfer to simulated table tennis play.

Although standard deviations of the index of transfer testified to large individual differences in the transfer of anticipatory and movement skills in all the groups tested, the largest were found among the senior female table-tennis players.

In order to find out the extent to which the components of the transfer index affect it in the test groups, the correlation coefficients between the range (R_l), speed of learning (S_l) and index of transfer (I_t) are calculated for these groups (table 2).

Table 2. Coefficients (C_c) of correlation between the speed (S_l), range (R_l), of learning and index of transfer (I_t)

Index of transfer (I_t) for :	The speed of learning (S_l)		The range of learning (R_l)	
	C_c	p	C_c	p
Children t-t	0.87	0.001	– 0.57	0.005
Male juniors t-t	0.79	0.006	x	x
Female seniors t-t	x	x	– 0.8	0.05
Male seniors t-t	0.65	0.03	– 0.64	0.03
Tennis players	0.80	0.01	– 0.54	0.05
Other sports	x	x	– 0.66	0.03

p – level of significance, x – statistically insignificant results.

In the case of the juniors, there was a statistically significant correlation only between the magnitude of transfer and the flexibility with which existing anticipatory experiences and ball hitting skills were modified (flexibility of possessed skills). For the senior females and the group of other sports, the index of transfer was correlated only with the range of indispensable modification of anticipatory and motor skills, while among children, senior males and tennis players it was correlated with both of these factors – with equal strength in the case of the former, but more with speed than range of learning in the latter.

4. Conclusions

The proposed manner of investigating transfer in sport permits:

• the analysis, by means of the range of learning (R_l), of the degree of resemblance of individual anticipatory experiences (anticipatory skills) and previously learned ball hitting movements to the experimental conditions (identical in each case: simulated anticipatory schemas and strokes),

• the analysis, based on the speed of learning (S_l), of resistance to modifications of existing anticipatory and motor skills,

• transfer to be expressed by means of a single index (I_t), the ratio of S_l to R_l, which is a holistic reflection of the degree of transfer of particular skills into others, or the capacity to learn new skills.

The investigations have shown that:

• the convergence of real with simulated play, the flexibility of existing skills and magnitude of transfer were the greatest among senior females, children and tennis players,

• the magnitude of transfer and the degree of similarity between real and simulated play (factor R_l – range of learning) were approximately the same among both senior males and junior males,

• among the table tennis players the lowest flexibility of existing ball hitting skills (factor S_l – speed of learning) was found in the group of senior males ($S_l = 0.28$),

• the lowest speed of learning ball hitting skills in the other sports ($S_l = 0.23$) was due to the fact that this group had to learn these skills practically from scratch,

• among children, seniors and tennis players the index of transfer is correlated with both range and speed of learning,

• among senior females and the other sports the index of transfer is correlated only with the degree of convergence of real and simulated table tennis play (factor R_l),

• among juniors the index of transfer is correlated only with learning speed (flexibility of possessed skills).

The manner of research presented in this article is suitable for use wherever learning curves are involved. When such learning is based on experience, knowledge and previously acquired skills, the method can be applied to measure transfer. In the investigation of learning without recourse to earlier experiences and skills, this method permits the analysis both of this process and of learning ability expressed by the range (qualities of memory) and rapidity of learning (the speeds and qualities of information processing its modification in the memory).

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