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VARIABLE PRACTICE IN LEARNING THE FOREHAND DRIVE IN TENNIS[1]

STAVROS J. DOUVIS

University of Athens

Summary.—One of the most important factors that has occupied researchers in motor learning is the method of practicing motor skills. This study examined the effect of variable practice in learning the forehand drive in tennis by children and adolescents. Variability of practice was achieved by the alternation of targets and the distance between the point of execution and the target. 40 male children ages 9 to 10 years and 40 male students ages 18 to 19 years were divided into eight equal groups according to age and training group (No Specific target, 1 target, 4 targets, and 5 targets). After 18 practice sessions over 40 days and similar teaching, the participants performed 60 transfer trials after a rest of 72 hours. The experimental design used was a 2 (age) × 4 (practice group) × 6 (block of trials) with repeated measures on the last factor for absolute and constant error scores. The analysis of variance showed that the children performed more poorly than the adolescents, and variable practice yielded better performance than constant and specialized practice. The results support the variability of practice hypothesis and indicate that the effect of variable and specialized practic was related to age of the groups of trainees.

Considerable research on motor learning has focused on the effects of contextual interference (Magill & Hall, 1990; Brady, 1998), knowledge of results (Schmidt, 1991; Travlos & Pratt, 1995; Travlos, 1999c), practice distribution (Lee & Genovese, 1988, 1989), and variability of practice (Shea & Kohl, 1990; Schmidt & Lee, 1999) on the retention and transfer of motor skills. The previous results agree regarding the importance of knowledge of results and practice composition to motor skill acquisition. Theoretically, variable practice (Wulf & Schmidt, 1997) and appropriate knowledge of results manipulation (Travlos, 1999a, 1999b) strengthen learners' generalized motor programs and memory representations to achieve the desired movement goal.

The concept of variability of practice is a core feature of schema theory (Schmidt, 1975). Variable practice refers to the sequence of practice of specific motor skills that are not performed in a strict, specified order; instead, a trial differs from the previous and subsequent trials. Comparing constant practice to variable practice, research generally supports the positive effects of variable practice in motor learning. Variable practice leads to poorer performance than constant practice in the acquisition phase but to superior per-

[1]Address correspondence to Dr. Stavros J. Douvis, 61 Nafsikas Street, Palaio Faliro, 175 64, Athens, Greece or e-mail (sdouvis@cc.uoa.gr).

formance in retention and transfer phases (Schmidt, 1975; McCracken & Stelmach, 1977; Catalano & Kleiner, 1984).

Lee, Magill, and Weeks (1985) considered the comparison between constant and variable practice "inappropriate" and suggested differentiating between random variable practice and blocked variable practice. In blocked variable practice, motor skills are grouped, whilst in random variable practice the skills are performed in random order (Shea & Morgan, 1979; Magill, 1998). Laboratory research has shown that random variable practice leads to better performance than blocked variable practice (Lee & Magill 1983; Shea & Zimny, 1983; Goode & Magill, 1986).

Reviewing the literature (see Shapiro & Schmidt, 1982; Magill & Hall, 1990), it appears that most research with children and timing and ballistic tasks shows that variable practice affects motor learning positively. According to Shapiro and Schmidt (1982), variability of practice had more positive effects in children than in adolescents. However, van Rossum's review of the literature (1990) indicated that research with children as subjects partly supports the variability of practice hypothesis. The variability of practice doubtlessly provides better performance when the task in the transfer phase is beyond the time limits (proximity effect) the practice task covers (Newell & Shapiro, 1976). Also, it appears that the influence of variable practice depends on the experience of the individual (Del Rey, Wughalter, & Whitehurst, 1982), the transfer phase (Lee, *et al.*, 1985), the sequence of presentation of variability (Newell & Shapiro, 1976), and the kind of motor skill (Barto, 1986).

In tennis, the preparation of every athlete aims at the development of motor skills which can be achieved as quickly as possible. The coaches and instructors of beginners place great emphasis on learning correct movement (technique) and less on the first stage of initiation, hitting the ball to a specific point on the opposite court in relation to the speed of the ball (Douglas, 1991, 1995). The careful observation of top tennis athletes indicates that the "orthodox" technique of movement does not always constitute a guarantee of success (Douglass, 1991). It must be stressed that successful performance by an athlete is the result of good anticipation skills (Williams, Ward, Knowles, & Smeeton, 2002), appropriate technique, and the co-existence of many other factors such as physiological and psychomotor adjustments and psychological preparation (Hutslar, 1993).

Coaches of beginners in tennis, when teaching the first stage of technique, apart from the "kinetically" correct execution of movement, urge them in a stereotypic way to "pass the ball over the net and into the opposite court" (Douglas 1995). This procedure is generally acceptable and, if in a short time the beginners manage to hit the ball to whatever point in the opposite court with a good technique, is considered a success for the coach.

In the second stage of teaching, the targets in the court become smaller and more specific. The coach chooses different areas in the opposite court and stresses to the athletes to hit the ball to the chosen area. In the third stage of teaching, the targets are the same, but the athletes are required to send the balls to specific targets faster (Heldman & Lumiere, 1976; Douglas, 1995).

It is reasonable to ask the question why the three aforementioned stages of teaching should be followed rather than simply beginning with the second stage, where "technically" the first stage of teaching is included. One of the purposes of this research is to unite the first and second stages of teaching "chronologically." This can be done by placing targets at different points in the opposite court. Following this procedure replaces the simple "passing of the ball over the net," as the required purpose of the first stage of teaching. More time is ensured for more productive practice, since the trainees do not wait for the beginning of the second stage to acquire the complete picture of the required basic goal, which is hitting the ball with the racket and aiming at a specific area in the opposite court. The proposed combining of the two stages provides the athlete with a complete picture of the general motor program, which is required for the successful execution of a specific shot.

The purpose of this study was to examine the effect of variable practice on the forehand drive in tennis by children and adolescents. The variability of practice was defined by the alternation of goals and the distance between the point of execution and the target. After providing an extended training program and uniform teaching, the statistical hypotheses of the research tested the most productive method of practice leading to learning after a 72-hr. rest for children and adolescents. More specifically examined was whether (a) variable practice of the forehand drive leads to different performance by children and adolescents than constant practice and (b) practice combining the usual two initial steps of learning in tennis results in better performance than teaching these separately.

Method

Participants

Forty boys in the fourth grade of elementary school (who ranged in age from 9 to 10 years) and 40 male first-year undergraduate university students (who ranged in age from 18 to 19 years) participated. No participants had previous experience in tennis or any other racket sport, and they signed a consent form before participating. In the elementary school children, participation was ensured with a permit from the appropriate office of Elementary School Education, and the consent form was signed by one of their parents. The participants were informed about the purpose and the nature of the

study and were free to withdraw from the study without further explanation and without any consequences.

The elementary school students were selected from four different schools. The choice of the schools was made based on (a) the distance of the schools from the tennis courts so that quick and safe access could be ensured for the students, (b) the existence of a sufficient number of male students in each class who had no prior experience with tennis or other racket sports, and (c) the place of residence so that the same origin of subjects was ensured for the most part regarding socioeconomic status. The participants were randomly assigned to one of the four groups.

The fourth grade students were selected because this period of life has been suggested as ideal for acquiring complex motor skills (Eckert, 1987). Physical conditioning at this age is better compared with that of younger children, and prerequisite physical abilities for tennis, such as reaction time, strength, and flexibility, are developed better at this age (Eckert, 1987). Also, children at this age can participate in organized athletic activities (Haywood, 2001).

The undergraduate students were selected from the required physical education program at the University of Athens because tennis courts were available at the place of study. They had roughly the same level of motor experience, and there were a satisfactory number of male students who had no prior experience with tennis or other racket sports. The participants were randomly assigned to one of the four groups.

Procedure

Tennis instructors.—The coaching staff, apart from the main researcher, was composed of four experienced tennis instructors. The instructors were especially trained for the research to use the same method of teaching and correcting the selected motor skills. Their instructions were focused on the use of the racket and the correct contact of the racket with the ball. The four instructors were randomly assigned to one of the four practice groups and trained both the children and adolescents. During each practice session, the participants had to warm up, become acquainted with the racket and the balls, and perform the forward swing of the racket for hitting the ball in the forehand drive. All participants received identical and stereotyped verbal knowledge of performance regarding technical mistakes, holding the racket, corner movement of the head of the racket in the forward swing, and finally, speed of the movement of the head of the racket. Moreover, the researcher observed the trainees and the instructors to ensure that each instructor followed the planned rules of behavior.

Practice phase.—To ensure conditions for the predictions of the variability of practice hypothesis, all eight groups practiced the forehand drive from

a fixed point of execution. The four practice targets were placed at the back of the court, and there was significant difference in distance between the targets and the point of execution of the motor skill (Fig. 1 below). The target distances from the point of execution were 17.30 m (Target 1), 18.50 m (Target 2), 19.30 m (Target 3), 20.20 m (Target 4), and 18.10 m (Target 5). Groups of 1, 4, and 5 targets (Groups A, B, and C, respectively) received knowledge of results, which was noted as the deviation of each shot from the predetermined goal. For the control group (Group D) knowledge of results was qualitative and limited only to the phrase "ball over the net."

Practice session.—The practice session lasted six weeks. The participants practiced under a common program three times a week for 1 hr., and each daily practice had four stages. The first three of the four stages were stable for all six weeks.

The first stage included warm-up exercises for 5 min. The second stage had exercises to familiarize the participants with the racket and the ball, which lasted for 5 min. The third stage had the methodical teaching of the swing of the racket in the forehand drive, which lasted 10 min. on the first three days of practice. After the third day the duration of methodical teaching was reduced to 5 min. Before every exercise in this stage of practice the coach demonstrated the movement 10 times. The participants watched the demonstration, and then the whole group simultaneously executed 20 moves.

In the fourth practice stage each participant executed 100 forehand drive shots from the execution point. The ball was served by the coach using the drop method and was the same for all participants (Douglas, 1991; Hutslar, 1993). The execution procedure was the same for all participants. During this stage, participants were divided into two groups of five people, and they worked on two courts. Each participant went to the point of execution and from a ready position the procedure of the execution of the forehand drive began. The left shoulder was vertical to the net, the left leg was at the point of execution, and the opening of the legs was a little wider than the shoulders. The head of the racket was level with the participant's head. From this point the racket started to descend, and the body weight was transferred to the left leg which came out towards the ball served by the coach using the drop method. The racket continued to descend until its head reached the lowest point, and it passed next to the back of the right leg and started its forward ascent. The racket continued its forward ascent and met the ball in front of the hip, with the wrist steady and the head slightly inclined downwards. The slightly bent legs aided the ascent of the racket with a stretching movement, which began immediately after the shot. After the shot, the racket continued its forward ascent following the same course until the handle was in front of and at the height of the left shoulder. The

leg continued to lift upwards to the point at which the front leg was almost stretched. Subsequently, the participant received knowledge of results of the outcome of the attempt and knowledge of performance for the technique of execution (see below). Then, the participant went back to the getting ready position and in the same way executed nine more attempts. A resting period of a few minutes followed, and after the participation of the other four participants, the first participant returned to execute 10 more attempts. This continued until he had completed 100 attempts.

Group A of the participants performed 100 trials of the forehand drive hitting at Target 5 (Fig. 1). Group B practiced hitting at Targets 1, 2, 3, and 4, executing 25 forehand drives toward each target. Group C practiced hitting at Targets 1, 2, 3, 4, and 5, executing 20 forehand drives at each target. Group D (control group) executed 100 forehand drive shots without a specific target on the court. The singular purpose of this group was to pass the ball over the net and have it drop on the opposite court. A red cone designated each target. The sequence of execution to targets for Groups B and C was not the same, but a counterbalanced sequence was applied. On the first day of practice the participants executed shots to Targets 1, 2, 3, and 4 (4 and 5 for Group C), on the next day to 2, 3, 4, and 1 (5 and 1 for Group C), and so on. This method was chosen so that the participants would not start with execution of shots to the same target.

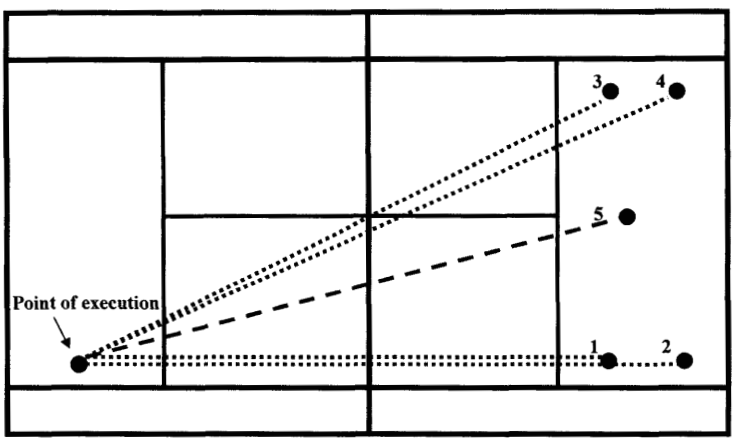

FIG. 1. Targets 1, 2, 3, 4, and 5 and point of execution for the forehand drive

After the execution of the forehand drive, the instructor gave knowledge of results (centimeters away from the target) and knowledge of performance for Groups A, B, and C. Knowledge of performance was followed by

any of four technical corrections: (a) the head of the racket at the starting point, (b) the head of the racket before the shot, (c) the head of the racket at follow-through, and (d) the steadiness of the grip at the handle (avoiding any activity of the hand).

At the end of the sixth week, the participants of both groups had undergone the same training, had made the same number of attempts, and received knowledge of results and knowledge of performance in the same way.

Transfer test.—All participants performed a transfer test after a 72-hr. rest. The transfer test was the execution of the forward drive to a specific point on the court (target at point 5, Fig. 1) and was the same for all participants. The court and the point of execution was the same as that which was used in the practice phase. Each participant performed 60 trials of the forehand drive from the point of execution, and the task was to hit the center of the target. All 60 trials were executed in the same way as in the practice phase (every 10 attempts). The serving of the ball was the same for all the participants and was executed by the instructors. After every attempt the instructors gave directional knowledge of results in centimeters to all participants. Deviation towards the back line of the court was recorded as positive and the deviation towards the side of the net as negative. All trials on which the ball did not pass the net were registered as nonsuccessful and were extrapolated according to the mean of that block of practice. The extrapolated trials were not more than 2 in the performed 60 trials for children and students, respectively. (Statistical analyses with the mean nonsuccessful trials omitted or extrapolated were not statistically significant.)

Data Treatment and Statistical Analyses

The dependent variables chosen for further analyses were absolute error and constant error. The calculations were made according to Schmidt and Lee (1999). According to Newell (1976), absolute error is the most suitable dependent variable for the assessment of the accuracy of performance relating to the target. Constant error was used to define the fluctuation and the course of performance towards the specific target.

The experimental design used was a 2 (age) $\times$ 4 (practice group) $\times$ 6 (blocks of practice) with repeated measures on the last factor for absolute and constant errors. Each block of practice constituted 10 trials. All statistical assumptions concerning experimental designs with repeated measures were examined following Stevens (1986). When the assumption of sphericity had been violated, the *df* were adjusted as needed for the Greenhouse-Geisser epsilon (Geisser & Greenhouse, 1958). To pinpoint the significant mean differences for the statistically important main effects and interactions, *post hoc* analyses were carried out applying Tukey's method. The α was set at .05 for all statistical and *post hoc* analyses.

Results

Means and standard deviations of absolute and constant errors for each age, practice group, and blocks of practice are presented in Tables 1 and 2, respectively.

Absolute Error

The analysis of variance of absolute error scores showed significant main effects for age ($F_{1,72} = 156.4$, $p < .0005$), practice group ($F_{3,72} = 80.6$, $p < .0005$), and blocks of practice ($F_{3.81, 274.24} = 5.3$, $p < .001$).[2] Only one significant difference for interactions was noted, in the interaction between age and practice groups ($F_{3,72} = 13.9$, $p < .0005$). The means for the age by practice group interaction are plotted in Fig. 2.

The significant mean difference between the two is due to the lower performance of the children ($M = 216$, $SD = 63$) than that of the adolescents ($M = 150$, $SD = 32$). The *post hoc* analysis of the practice group main effect showed that the groups who practiced without a target ($M = 230$, $SD = 51$) and with one target ($M = 216$, $SD = 63$) were inferior to those with four ($M = 158$, $SD = 32$) and five targets ($M = 131$, $SD = 15$). The group who practiced

TABLE 1

Means and Standard Deviations of Absolute Error Scores (cm) For Children and Adolescents as a Function of Practice Groups Across Blocks of Practice

		Block of Practice					
		1	2	3	4	5	6
Children							
Group A	*M*	291	282	271	281	251	244
	SD	79	48	65	73	55	46
Group B	*M*	289	264	282	244	278	263
	SD	56	54	64	51	49	54
Group C	*M*	182	187	192	182	189	187
	SD	41	25	32	34	45	18
Group D	*M*	150	151	167	125	125	114
	SD	50	36	33	40	18	18
Adolescents							
Group A	*M*	197	183	187	198	180	193
	SD	41	28	36	36	29	24
Group B	*M*	164	149	153	169	171	163
	SD	27	29	23	32	21	22
Group C	*M*	156	133	122	136	119	113
	SD	47	25	16	32	18	28
Group D	*M*	153	140	123	115	103	102
	SD	27	25	17	15	33	20

[2]Adjusted *df* for Greenhouse-Geisser epsilon.

TABLE 2
MEANS AND STANDARD DEVIATIONS OF CONSTANT ERROR SCORES (CM) FOR CHILDREN AND ADOLESCENTS AS A FUNCTION OF PRACTICE GROUPS ACROSS BLOCKS OF PRACTICE

		Block of Practice					
		1	2	3	4	5	6
Children							
Group A	*M*	−217	−147	−185	−178	− 94	− 77
	SD	141	190	126	177	161	154
Group B	*M*	−176	−171	−194	−154	−148	−155
	SD	118	140	142	107	118	133
Group C	*M*	− 93	− 97	− 92	− 12	− 32	− 23
	SD	58	104	70	118	121	130
Group D	*M*	− 49	− 93	− 83	− 58	− 7	12
	SD	105	61	69	72	55	66
Adolescents							
Group A	*M*	−122	−121	−131	−117	− 68	− 86
	SD	53	54	60	82	73	63
Group B	*M*	−101	− 89	− 87	− 40	− 93	− 88
	SD	51	54	48	102	56	44
Group C	*M*	− 60	− 54	− 43	− 32	24	9
	SD	72	69	42	47	37	44
Group D	*M*	− 65	− 64	− 11	− 4	1	4
	SD	55	42	52	61	23	47

without a target did not differ significantly in mean performance from the practice group using one target. However, the practice group using four targets was inferior to the practice group using five targets. The significant

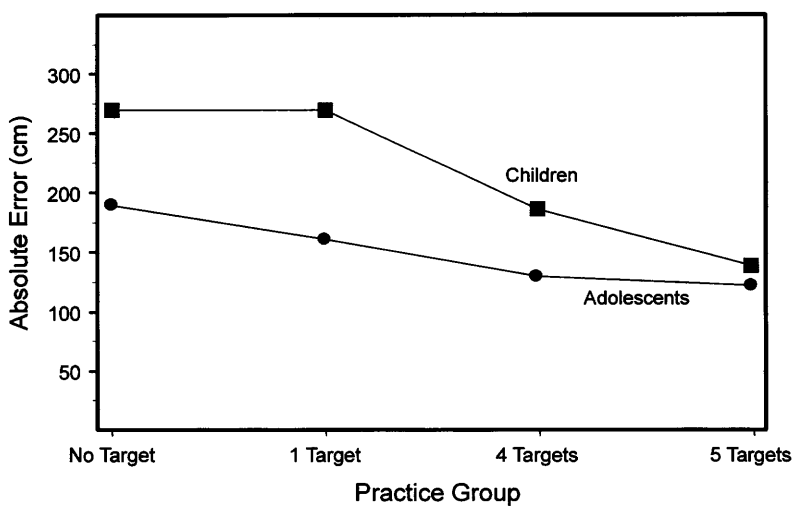

FIG. 2. Absolute error scores for children and adolescents as a function of practice groups

mean difference for the main effect of blocks of practice was due to the difference of the sixth ($M = 172$, $SD = 65$) with the first ($M = 198$, $SD = 72$) and second ($M = 186$, $SD = 63$) blocks of practice, and the fifth ($M = 177$, $SD = 68$) with the first block of practice.

The *post hoc* analysis of the significant interaction for age and practice group showed several effects. The children who practiced without a target had lower performance than the children who practiced with four and five targets and the adolescents of all practice groups with and without targets. The performance of the children who practiced with one target was lower than that of children who belonged to the practice groups using four and five targets, and all of the adolescent practice groups. The children in the practice group using four targets had lower mean performance than children in the practice group using five targets and adolescents who praticed with four and five targets. Children in practice groups using five targets had a higher performance than adolescents in the practice group without a target. The adolescents of practice groups without a target had significantly lower performance than those using four and five targets. The adolescents in the practice group using one target had a lower performance than adolescents in practice group with five targets. The remaining comparisons were not statistically significant.

Constant Error

The analysis of variance of constant error scores yielded significant main effects for age ($F_{1,72} = 19.2$, $p < .0005$), practice group ($F_{3,72} = 24.5$, $p < .0005$), and block of practice ($F_{4.03, 290,.05} = 7.3$, $p < .01$).[2] None of the interactions among factors were significant ($p > .05$).

The significant mean difference between the children and the adolescents was based on the overall worse performance of the children ($M = -105$, $SD = 79$) in relation to the adolescents ($M = -60$, $SD = 45$). The *post hoc* analysis of the main effect for practice group showed that the noticeable statistically significant difference (Fig. 3) was due to the lower performance of the practice groups with no target ($M = -129$, $SD = 56$) and with one target ($M = -125$, $SD = 72$) against the performance of practice groups with four targets ($M = -42$, $SD = 37$) and five targets ($M = -35$, $SD = 68$).

Concerning *post hoc* analysis for the blocks of practice main effect, (a) the sixth block of practice ($M = -51$, $SD = 107$) was significantly better than the first, second, and third ($M = -111$, $SD = 101$; $M = -104$, $SD = 104$; and $M = -103$, $SD = 100$, respectively) and (b) the fifth block of practice ($M = -52$, $SD = 104$) was considerably better than the first, second, and third blocks of practice. No significant mean differences were noted among the remaining pairs of compared groups.

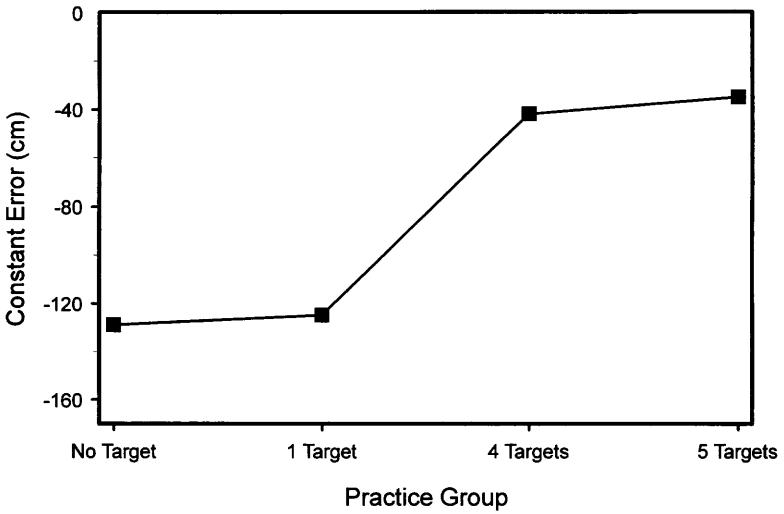

FIG. 3. Constant error scores as a function of practice groups

DISCUSSION

The study examined the effects of variable practice in learning the forehand drive in tennis by children and adolescents and assessed several methods of teaching motor skills in tennis. Two detailed reviews (Shapiro & Schmidt, 1982; Lee, *et al.*, 1985) indicated that the assumption of variability in practice is supported only when children are subjects, while similar results are not found for adults. However, a relatively recent review by van Rossum (1990) rejected the previous remark and stated that the largest part of research does not corroborate the anticipations of the variability of practice hypothesis either with children or with adults.

The present findings showed that adolescents executed the shots with greater accuracy than did the children. It is also worth noting that the divergence in accuracy of the shots was closely related to the age of the subjects and the practice composition (constant and variable). The finding that children performed better in variable practice groups (practicing using four or five targets) as compared to constant practice groups (practicing using 1 or no specific target) supports the variability of practice hypothesis and agrees with the findings of Kerr and Booth (1978) and Moxley (1979), whilst it disagrees with the findings of Pease and Rupnow (1983), Pigatt and Shapiro (1984), and Wrisberg and Mead (1981). Another finding worth mentioning in this research is that children who had specialized constant practice (practice and transfer in the same target) did not perform better than participants who practiced without a specific goal. Also, children who practiced with five

different targets (specialized and variable practice) performed significantly better than the 4-target practice group (variable practice), the 1-target practice group (specialized practice), and the no specific target group. These findings agree with the variability of practice hypothesis and indicate that in children, practice groups with a larger number of practice targets performed better than groups having fewer practice targets.

Examining adolescents' performance in the variability of absolute error scores, it was observed that the performance of the practice group with no specific target was lower than that of the groups using four and five targets, while not differing significantly from the mean of the group using one target. Furthermore, it is worth stressing that specialized practice did not significantly differ from variable practice (practice group using four targets) but was significantly different from variable-specialized practice (practice group using five targets). The results partially support the assumption of variable practice and agree with Kerr (1982), Lee, *et al.* (1985), Shea and Kohl (1990), and Landin, Hebert, and Fairweather (1993).

Comparing children's with adolescents' accuracy, children who had specialized-variable practice (five-target group) performed at the same level as adolescents practicing with one target (specialized practice), four targets (variable practice), and five targets (specialized-variable practice) and significantly better than adolescents practicing with no specific target. Moreover, children practicing with four targets (variable group) performed similarly to the adolescent groups praticing with one target (specialized practice) and no specific target. It appears that children have more to gain than adolescents through variable practice (Shapiro & Schmidt, 1982; Lee, *et al.*, 1985).

Regarding the consistency of participants' performance, the constant error analysis showed that for children the discrepancy from the target is higher than that for adolescents. The adolescents' performance was closer to the target, but they showed a pattern of discrepancy similar to that of the children. Examining the mean differences among the practice groups, it was observed that the consistency of four- and five-target practice groups was greater than that of the one- and no specific target practice groups. This finding indicates that, regardless of the ages in these two groups, variable practice yielded greater performance than specialized and constant practice (Wrisberg, Winter, & Kuhlman, 1987) and does not agree with the findings of Christina and Merriman (1977), who found that specialized practice leads to better transfer of learning for groups 17 to 33 years of age.

The findings of this study are of special interest theoretically and practically. It appears that the common way of teaching motor skills in tennis must move beyond the traditional three stages of practice. No advantage to the learner is gained using the first stage of teaching (ball over the net) as a means of learning motor skills. The advantages of variable, relative to spe-

cialized practice for learning the forehand drive, agree with the predictions of schema theory (Schmidt, 1975) and the findings of other studies which provided support for the variability of practice hypothesis (e.g., Shea & Kohl, 1990, 1991; Lai, Shea, Wulf, & Wright, 2000). According to the findings of this research, the learners who were taught and practiced the motor skill of the forehand drive without aiming at a specific target (no specific target practice group) continued to perform with less accuracy and consistency than the variable practice groups. Moreover, practice on a specific target did not ensure the fastest and most effective learning of this specific skill. On the contrary, it did not provide any facilitation when the participants were boys 9 to 10 years old, while adolescents who were prepared using the method of specialized practice performed similarly to the variable practice group and worse than the adolescents who followed specialized and variable practice. It appears that practice on a specific task for a long period of time may be detrimental to transfer of what was learned (for more information, see Travlos, 1999a, 1999b, 1999c).

Concluding, it is worth remarking that, although the findings of the present research deal with learning the forehand drive, they cannot be applied without caution to other similar motor skills of tennis, e.g., backhand drive. Programming the teaching of motor skills using the method of variable practice, instructors can facilitate faster and more effective learning of motor skills, especially if the participants are 9- to 10-yr.-old children. However, it is possible that a different relationship may apply in similar or more complicated motor skills for specialized practice to be superior to variable practice. For the aforementioned assumption to be studied in depth, more research is needed, using similar and complicated motor skills as the focus of the research.

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