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Article

Training Tennis through Induced Variability and Specific Practice: Effects on Performance in the Forehand Approach Shot

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Featured Application: This work offers a significant contribution to the field of competitive tennis training, providing players and coaches a training program based on the application of induced variability. It establishes a solid foundation for modulating the variability loads present in the real game and guiding the training towards the pursuit of maximum sports performance.

Abstract: (1) Background: Learning and training in variable conditions favors adapting to unstable or changing environments. The aim of the study was to test the effect of variable practice on the accuracy of the forehand net approach shot in tennis.; (2) Methods: Thirty (n=30) first-class national players (12.9 ± 1.1 years old) participated, divided into three groups: i) induced variability training (n=10) (varying court surfaces and balls), ii) specific training (n=10) and iii) usual training -control group- (n=10). All groups trained for a month: 12 sessions of 20 minutes -3 per week-. The accuracy of the shots were analyzed through a 2D capture and digitization process of the ball bounce on the court; (3) Results: The variability group presented better accuracy values after the period without practice than the stable training group (p = 0.041; ES= 0.51).; (4) Conclusions: the application of variability in the game conditions during tennis training seems to have a favorable effect on the retention of accuracy in the forehand down the line approach to the net.

Keywords: variable practice; tennis; forehand; approach net shot; ball type; tennis court

1. Introduction

Motor variability is a property of biological systems [1]. Humans are incapable of performing two identical movements, due to the large number of degrees of freedom present in movement [2]. Variability is present in a person's motor behavior and in their ability to adapt to the environment, which can be beneficial for performance in motor tasks [3]. This variability is multidimensional and appears not only in the motor system affecting motor patterns, but also during sports practice, in tactical situations posed by the opponent or under environmental conditions inherent to the game itself that affect performance, forcing the player to continuously adapt [4].

Considering variability as a characteristic present in the kinematics of movement and inherent to any game context, it would be reasonable to think that if it is present in the development of motor actions, variable practice or induced variability could be a means to consider to facilitate motor learning [5]. On the other hand, the variability induced in training can also provide flexibility to select or switch to new motor patterns when environmental conditions demand it, use previously learned movements, and allow access to the parameters that define these patterns [3]. In this sense, although variability is present in the execution of movement, these variations are often very small in magnitude, especially in expert athletes, and can be effective as a capacity to compensate for small deviations during the pursuit of performance [6].

Thus, in the practice of a sport like tennis, one can perceive the existence of variability in spatial conditions (e.g., surfaces) and in the instruments (e.g., characteristics of the balls) [7]. It has been

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confirmed through previous studies in other racquet sports, such as paddle tennis, that the type of ball and surface significantly affect the kinematics of the ball after the bounce, therefore affecting the shots and the motor actions of the players [8]. Even, some studies also consider it of interest to apply variability in the form of changes in competitive rules to generate influences on performance [9].

On the other hand, in high-performance tennis, since the tournaments of the Association of Tennis Professionals (ATP) and the Women's Tennis Association (WTA) are contested on different types of surfaces and using variations in the characteristics of the balls, players are obliged to train according to these factors to start the competition with an optimal degree of adaptation. The professional circuit begins with tournaments on hard court (medium-fast), such as the Australian Open; it continues with tournaments on clay court (slow), such as the Monte Carlo Open; it proceeds with tournaments played on grass (fast), like Wimbledon; and the season ends with the dispute, once again, of tournaments on hard court (medium-fast) [10]. In this way, the International Tennis Federation classifies the courts into three categories: i) Category 1 (slow bounce), ii) Category 2 (medium / medium-fast bounce), and iii) Category 3 (fast bounce). These categories aim to allow some flexibility in the selection of the ball among three possibilities: i) type 1, which is recommended for use on slow bounce surfaces; ii) type 3, which is 6-8% larger than the standard ball, causing greater deceleration, and is suitable for fast bounce surfaces; iii) the standard ball, type 2, which is in terms of bounce characteristics between the fast and slow ball, and is used on medium-fast courts [11].

Considering the aforementioned differences in surfaces and balls, we find it reasonable and necessary for the tennis player to develop adaptive mechanisms that allow them to adapt to the changing circumstances inherent in competitive tennis [3]. However, these training conditions in variability must be close enough to the real situation to avoid negative transfers, also considering the specificity in the training of racquet sports important for obtaining an adequate level of performance [12], as well as the quantification of the applied variability load [13].

Therefore, variability should be considered as a very important variable in this sport, which appears both in real game conditions and for the training of the players themselves through its systematic administration in training [14]. In this line, some research has demonstrated its effectiveness for the training of the forehand stroke from the back of the court in young tennis players, with modification of the spatial conditions [15].

In relation to another tennis stroke, such as the serve, [5] confirmed that effectiveness was not negatively affected after employing large loads of variability, varying rackets and balls in training. These investigations confirm that both the materials, mobiles and instruments used in the game, as well as the surface of the court [8,15,7], should be key considerations when coaches determine specific training programs for high-level tennis players [16,17].

In relation to all of the above, this research is proposed, whose main objective is to determine whether the application of induced variability on playing surfaces and types of balls in the training of the forehand approach shot in tennis, which is one of the most used shots in high-performance tennis [18], generates more accuracy than stable training and the usual training of tennis players. The study hypothesis is that training under conditions of induced variability will achieve better accuracy values than the other two proposed conditions.

2. Materials and Methods

2.1. Participants

The research involved 30 right-handed tennis players (age 12.9 ± 1.1 years; height 158.5 ± 8.3 cm; weight 55.12 ± 6.9 kg) of national level (n=30), first class in their respective youngest child categories: fry, infantile, and cadet, with more than 5 years of experience in tennis practice. All participants were informed of the risks and benefits of the study and provided a document with the express consent of their parents, following the Helsinki Declaration of the World Medical Association. The research was approved by the Bioethics Commission of the University of Extremadura -_Extremadura, Spain- (code 134/2015). The sample was randomly divided at the beginning of the research into three groups: i) induced variability, n=10, ii) specific training, n=10 and iii) usual training, n=10. The three groups

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were evaluated using the International Tennis Number -ITN- [10] which proposes a scale from 1 (best rating) to 10 (worst rating), with no significant differences between groups (ITN=4.91±1; *p*=0.033).

2.2. Measures and Instrumentation

To record the accuracy in the forehand approach shots to the net, a video camera was used, filming at a frequency of 150 Hz (Casio, model Exilim FH 100). Each bounce of the ball on the court was recorded using this video camera, fixed at a distance of 8 meters from the baseline of the tennis court and at a height of 4 meters, placed on top of the rear lighting and directed to the sending area marked as a target, with dimensions of 0.7 x 0.7 meters, located 1.0 meters away from the singles sideline and 1.0 meters away from the baseline. This location is considered ideal other authors [19] for accuracy tasks of these characteristics and using this type of strokes. In addition to taking as a point of maximum accuracy the spatial coordinates X -longitudinal- and Y -transversal- of the center of the target, the backcourt area of the singles game was established as a reference system, from the back line of the service boxes to the baseline, thus having a total of 5 coordinates to establish the reference system.

The recordings were played back using Kinovea v.0.9.5 software. Each X and Y coordinate of the reference system and the target was digitized and transformed into real coordinates, with an error less than 1.0 cm. The radial error (RE) was calculated as a measure of accuracy in the strokes using the formulae proposed by other authors [20] (Formula 1), applied to the digitized coordinates of each bounce of the ball on the court. Finally, the obtained data were processed for subsequent statistical treatment.

$$\mathbf{RE} = \sqrt{(x - x')^2 + (y - y')^2} \quad (1)$$

X and Y = longitudinal and transversal coordinate of the ball bounce on the court

X' and Y' = real coordinates of maximum accuracy according to the location of the target

Formula 1. Formula for obtaining accuracy in strokes through the calculation of radial error (RE).

The data collection was carried out on outdoor tennis courts, taking into account the wind speed, which can interfere with the speed and effectiveness of certain tennis strokes [21]. To control for this potential interference, an anemometer (Technoline EA 3000, United States) was used, and it was observed that during the measurement, the wind speed remained below 3.33 m/s. In this context, a study artificially inducing wind during tennis serve execution, demonstrated that intensities below 4.3 m/s did not negatively impact achieved accuracy [21].

In the context of maintaining consistency in ball delivery, a ball-throwing machine (Playmate Volley, United States) was employed to launch balls to the players. Prior to data collection, a reliability test was conducted, yielding the following results (Table 1)

Table 1. Reliability Test of the Ball-Throwing Machine.

N	**Launch Speed** ($Km \cdot h^{-1}$)	**Launch Frequency** (sec.)	**CV Launch Speed**	**CV Launch Frequency**
50	45,7± 0.6	4,6 ± 0,9	1,2 %	4,2 %

N: number of balls thrown; **CV:** Coefficient of variation.

The ball-throwing machine was calibrated before each trial, and the reliability of the device was assessed to observe the launch frequency and velocity based on the calculation of the coefficient of variation (CV). For launch velocity measurements, a mobile radar system (Stalker ATS 4.02; Radar Sales, Plymouth, MN, USA) was employed. The results of the reliability tests obtained in the frequency (CV = 4.2%) and in the throwing speed (CV = 1.2%) indicate a high degree of consistency, in line with other studies in which the same methodology was used [22].

To analyze the effect of the training sessions, a pre-test was applied before starting the intervention phase; a post-test after the training sessions, and a re-test one week after the post-test. Each of them consisted of 60 repetitions, 4 sets of 15 repetitions with 60 seconds of rest between sets

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and 4.6 seconds between strokes. All three groups performed all the tests under the same conditions, using standard intermediate bounce balls (type 2) and clay courts.

Prior to the tests, the players performed a general activation based on their daily routine: a brief warm-up of the main muscles with specific tennis movements, dynamic and ballistic exercises, and twenty minutes of exchanging strokes in different directions.

2.3. Procedure

The two experimental training groups, through induced variability and specificity, performed 60 parallel forehand net approach shots in each of the 12 proposed training sessions. Four sets of 15 repetitions each were performed, with 60-second breaks between sets and 4.6 seconds between strokes, corresponding to a hitting frequency of 13 strokes per minute (Table 2). This throwing frequency has been observed as optimal to achieve the best percentage of hits through an appropriate technique in competition players [22]. The players had to perform a parallel approach shot aiming to hit the ball in the center of the target.

Table 2. Structure of the experimental groups' training.

Groups	**Court surfaces**	**Balls**	**Sets**	**Rep.**	**BTF (sht·min^{-1})**	**Breaks (sec.)**	**Sessions**
Variability	Slow (clay)/ Fast (concrete)	Fast, slow, intermediate	4	15	13	60	12
Specificity	Slow	Intermediate	4	15	13	60	12

Rep. = Repetitions performed in each training session; **BTF** = Ideal ball throwing frequency; **sht·min^{-1}** = Shots per minute; **sec.** = Seconds.

The induced variability group trained on two types of surfaces - fast (concrete) -hard court- and slow (clay) balanced every 3 training sessions, until completing the four weeks it lasted (12 sessions) and using in each of the sessions the three types of balls based on the speed after the bounce (slow, intermediate, and fast), randomized in series of 9 trials. The specific training group trained only on a slow surface, until completing the four weeks, using the same type of ball (intermediate) in each of the sessions (Figure 1).

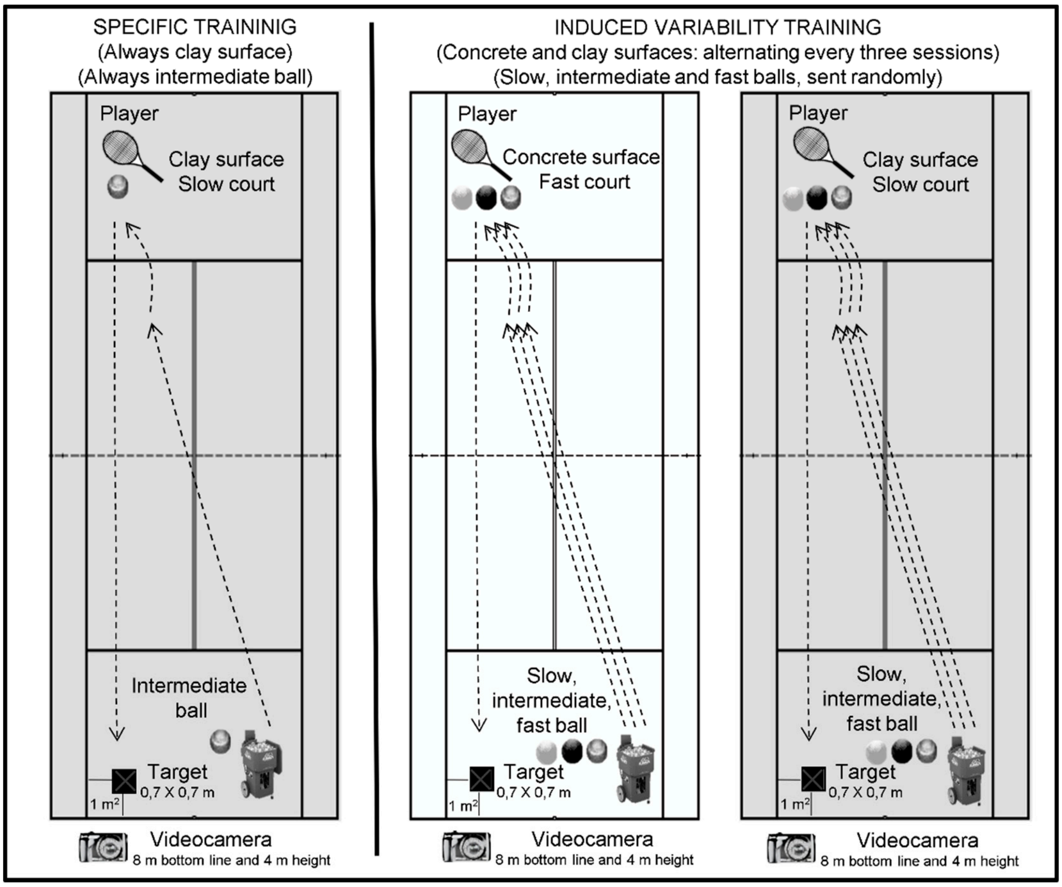

Figure 1. Experimental setup.

The control group carried out their usual training, similar in number of days and training hours per week to the two experimental groups. Thus, they trained on a clay surface - slow court -, three days a week for a month (12 sessions), with sessions of 1 hour and 30 minutes. This group trained with intermediate balls (type 2), which are the conditions in which all groups (control, specificity, and variability) normally train in their daily practice.

2.4. Statistical Analysis

The software package SPSS v.29.0 for Windows (SPSS, Chicago, IL-EEUU) was used for the data statistical analysis. The significance level for statistical tests was p ≤ 0.05. The Saphiro-Wilk test detected a lack of normality in the data distribution. Attending to these results and the sample size, it was applied a non-parametric H of Kruskal-Wallis to confirm the effects of practice schedules between groups. Effect sizes (ES) were estimated by calculating epsilon-square (E_R^2). This coefficient assumes the values from 0 (indicating no relationship) to 1 (indicating a perfect relationship). The Friedman ANOVA was applied to find effects of the practice schedules between tests on each group. Effect sizes (ES) were estimated by calculating the Kendall's W test (W). This coefficient assumes the same values to epsilon-square (E_R^2).

3. Results

The accuracy results - radial error - of each of the training groups - usual, stability, and induced variability - are shown in Table 3. The values recorded in the pre-test, post-test, and re-test are included.

Table 3. Descriptive values (cm) by groups and practice schedules.

		Usual	Specificity	Variability
Radial Error Pre-test	Mean	206,97	230,77	232,94
	Stándar deviation	36,21	48,45	30,69
	Median	203,63	231,54	235,76
	Variance	1311,03	2347,14	942,13
	Stándar error	11,45	16,15	9,71
	N	10	9	10
Radial Error Post-test	Mean	100,42	98,18	165,75
	Stándar deviation	22,14	22,34	111,42
	Median	95,58	97,92	110,22
	Variance	490,20	498,93	12414,71
	Stándar error	7,00	7,06	35,23
	N	10	10	10
Radial Error Re-test	Mean	201,85	241,69	192,60
	Stándar deviation	44,22	43,50	46,23
	Median	180,09	236,44	180,46
	Variance	1955,62	1892,41	2137,61
	Stándar error	13,98	13,76	14,62
	N	10	10	10

3.1. Between-Groups Analisys

Figure 2 presents the results of the inter-group analysis. Significant differences are observed in the retention test between the practice groups in induced variability (192.60 ± 46.23 cm) and in specificity (241.69 ± 43.50 cm). The variability group presents better accuracy values than the specificity group after the period without practice (***p*** = 0.041; ***ES***= 0.51).

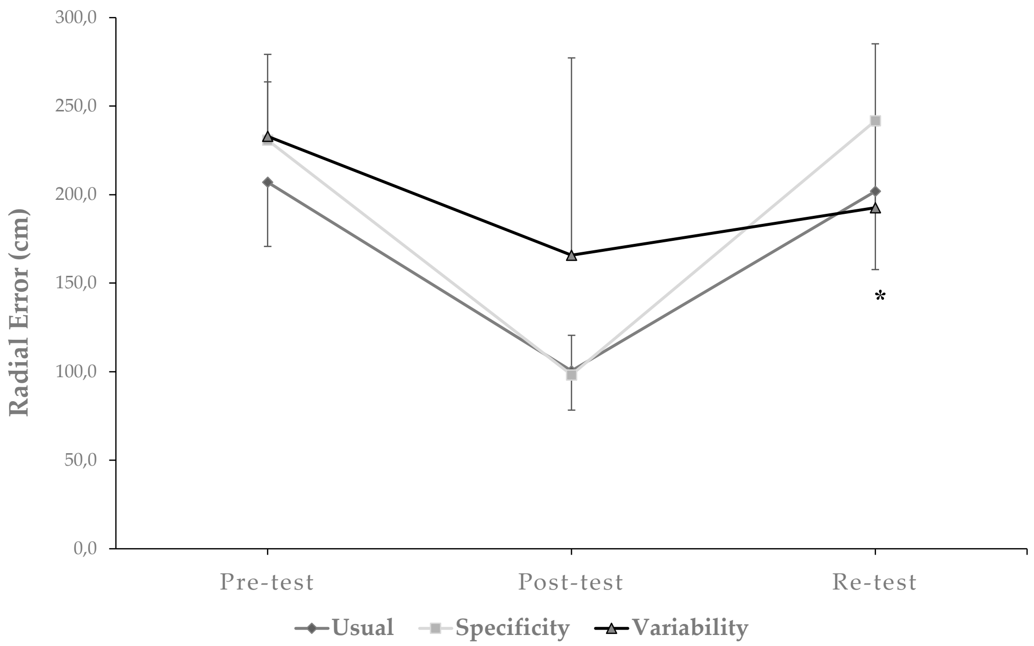

Figure 2. Evolution of the accuracy achieved by the players in each practice condition from the pre-test to the retention test. The bars show the standard deviation. * ***p*** = 0.041; ***ES***= 0.51; Significant differences between the specificity and variability groups in the retention test.

3.2. Intra-Group Analisys

In the usual training group, there were significant increases in accuracy in the post-test (***p***=.001; ***ES***=0.32). However, a significant loss of accuracy is observed between the post-test and the re-test (***p***=.005; ***ES***=0.28). In the specific training group, there were significant increases in accuracy in the post-test (*p*=.003; ***ES***=0.31). On the contrary, a significant loss of accuracy is observed between the post-test and the re-test (***p***=.007; ***ES***=0.29). In the variability training group, no significant changes in accuracy were produced derived from this practice condition.

4. Discussion

In this research, the effect of training through induced variability, specific and habitual, on the accuracy of the right net approach shot in tennis was analyzed.

Regarding the intra-group comparison, it is noteworthy that the variability group presents better accuracy values than the stability group after the period without practice, that is, in the retention test, compared to the post-test. These results are in line with other studies, which have reported greater accuracy after practicing tennis under variability conditions than when doing so in specificity, with young tennis players who practiced the tennis service [23].

Focusing specifically on the stroke treated in the present study, the results found agree with other researchers [15], on the influence of variable practice in learning the forehand, although it was not specifically analyzed, as in our case, in a situation of approaching the net. In that study, both a group of children aged between 9-10 years and another group of young students aged between 18-19 years obtained a higher performance practicing the forehand in a variable way than doing it in a specific way. Similarly, previous studies confirmed positive effects on the right approach to the net in tennis after applying variability loads through the use of weighted wrists by amateur players [24].

The results observed in the different training conditions on the forehand net approach shot must be understood from the perspective of the reality of the game. It must be considered that the situations that occur in a tennis match present unpredictability, uncertainty, and a reduced reaction time to make decisions. In this sense, the results in which the accuracy of the stroke is only improved in the retention test by the group that trains in variability, could be related to the adaptations produced by this type of training.

Thus, they could especially be in line with a greater adaptive capacity or positive transfer to tennis performance when, for example, the player has to go, in a short period of time, from competing on a slow court to a fast court, as happens in the professional tennis circuit [10] [25].

On the other hand, the fact that no significant differences were found between the three groups in the post-test leads us to think about issues related to the quantity and intensity of the load, especially the one induced in variability, which has not allowed us to fully accept the study hypothesis. In this sense, we agree with other authors, who affirm the importance of carrying out an individualized application of variability loads to achieve the best possible effects on tennis performance [13]. This issue reflected in the results of our research suggests the need to develop new studies that clear up these unresolved questions.

This issue about the induced variability load would also explain the results observed in the intra-group comparison. In the specific and habitual training groups, there were significant increases in the accuracy of the forehand approach shot in the post-test compared to the pre-test. On the contrary, in these groups there was a significant loss in the re-test compared to the post-test, which is why we cannot talk about a maintenance of performance over a week. For its part, the practice group through induced variability does not significantly improve accuracy after the training period or even after the period without practice. This result does not coincide with previously obtained, which confirmed positive effects on the forehand approach to the net in tennis, after applying variability loads through the use of weighted wrists, by amateur players [24]. However, we understand that the variability induced in this study was carried out with amateur players who present a wide range of improvement and differs greatly from that applied in our research with competition tennis players who do not present so much margin. Therefore, this lack of coincidence should be assessed with caution.

These results reinforce the need to apply individualized variability loads, adjusted according to a detailed analysis of their effects on game performance that impact in the short, medium and long term. In fact, other authors who investigated the effects of different variability loads, in the format of contextual interference, applied to tennis service training, conclude that their results are not so evident in complex motor skills, as is the case with the right approach shot analyzed in our study [26].

Additionally, another factor that could explain this result would be the possible onset of fatigue, as some authors have concluded that it could affect motor memory during the practice of sports skills [27]. However, this explanation requires scientific verification, in order to modulate the training load in this action of the game in tennis so that it does not negatively affect performance.

Future research directions emanating from this study should address the individualized quantification of induced variability loads in the learning and training of tennis strokes. It is considered a priority to abandon group studies and carry out intra-subject research designs, as there are too many uncontrollable factors during the practice of this sport, as well as those specific to each player among which may be aspects such as fatigue or others, which can condition the effects of these types of programs based on the generation of variability on the accuracy achieved in the strokes.

5. Conclusions

As the main conclusion of our research, we highlight the idea that the use of variability in the conditions of tennis training seems to have a favorable impact on the retention of performance in accuracy of the forehand parallel approach shot to the net. It is necessary to know the characteristics of the variability inherent to the sport in question, in our case tennis, in order to be able to design workloads and training systems aimed at improving certain variables associated with sports performance. These variability loads must be sufficiently adjusted to stimulate an increase in performance, without exceeding the levels of variability to limits that could generate negative transfers and, consequently, negatively impact performance.

In this research, we have tried to maintain a high ecological value by manipulating the practice conditions according to the reality of the tennis game. The induced variability loads have been based on the manipulation of variables that are usually present in competitive level tennis players, however, it seems necessary to continue investigating the intensity and quantity of these loads and their impact on performance in terms of accuracy in the strokes.

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Informed Consent Statement: Informed consent was obtained from all subjects, parents and legal guardians involved in the study.

Data Availability Statement: Data Availability Statements are available in https://www.preprints.org/.

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Conflicts of Interest: The authors declare no conflicts of interest.

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