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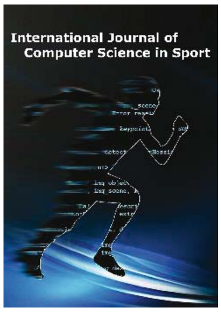

Comparison of the Evaluation of Performance Preconditions in Tennis with the Use of Equal and Expertly Judged Criteria Weights

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Abstract

Tennis performance is influenced by various factors, among which physical performance factors play an important role. The aim of the study was an analysis of possibilities of the use of Saaty's method for assessing the level of performance prerequisites and comparing the results obtained using equal weights and various weights. The research on Czech female players (U12; n = 211) was based on the results of the TENDIAG1 test battery (9 items) and the results were processed by FuzzME software and relevant statistical methods (correlation coefficient r, Student´s t-test, effect size index d). The results of Saaty's method show that the most important athletic performance criteria for tennis coaches are the leg reaction time and the running speed, while the least important are endurance and strength. The evaluation using various criteria weights offers a finer scale for assessing athletes' performance prerequisites despite the proven high degree of association between the results obtained with equal and various weights and the insignificant difference of mean values. The results have shown possibilities for the use of a fuzzy approach in sports practice and motivate further research towards broadening the structure or the number of evaluation criteria.

KEYWORDS: FUZZY LOGIC, SAATY´S METHOD, FUZZME SOFTWARE, TENNIS PLAYERS

Introduction

Sports performance is a complex activity for solving a sporting task and is always performed in a specific person-task-environment constellation. Sports performance is influenced by various factors, with those most often mentioned being somatic, physical, technical, tactical and psychological factors, with emphasis also being placed on the importance of their interactions. Although sport-specific technical skills are extremely important to tennis performance, a complex profile of physical performance factors is also required (Fernandez-Fernandez, Ulbricht, Ferrauti, 2014; Güllich, & Krüger, 2013; Hohmann, Lames, & Letzelter, 2010). The most important fitness factors are considered to be speed, coordination and strength, since a tennis player well-prepared in terms of fitness has much better preconditions for attaining an optimal sports performance and a high standard of performance (Fernandez-Fernandez et al., 2014; Ferrauti, Maier, & Weber, 2014; Schönborn, 2010; Ulbricht, Fernandez-Fernandez, Mendez-Villanueva, & Ferrauti, 2016). The level of fitness preconditions is often determined by means of batteries of tests, with field-based methods being considered to be more appropriate for sports such as tennis. Diagnostics of the level of performance preconditions make it possible to check, regulate and manage the training process and to individualise and objectivise training interventions; they also play an important role in the selection of sporting talent (Fernandez-Fernandez, Ulbricht, & Ferrauti, 2014; Ferrauti et al., 2014; Hohmann et al., 2010; Zháněl et al., 2015). The principle of assessment of individual tests is generally based on classical set theory (binary logic), which works with sharp boundaries between sets and the elements either belong or do not belong to a set. A concept based on the theory of fuzzy sets also admits the possibility that a given element belongs only partially to a set and is generally understood as an alternative to the conventional demands of determinism and exactitude. The theory of fuzzy sets was created by Zadeh (1965) as an alternative to classical (binary) logic and pointed to the fact that the use of sharp boundaries may be unsuitable in certain cases in which binary logic fails. Since its inception, fuzzy logic has gradually been applied in many fields of human activity, such as geography (Božić-Štulić, Kruzic, Gotovac, & Papić, 2018), medicine (Das, Chowdhury, & Saha, 2012), economics (Shin, & Wang, 2010) and digital technology (Sagar, & Babu, 2012), while it is also widely used in domestic appliances such as washing machines and microwave ovens, in transport in the operation of traffic lights, and in banking.

In recent decades, fuzzy theory has also begun to be applied in sports (Leist, 1996; Novatchkov, & Baca, 2013) such as cricket (Ahamad, Naqvi, & Beg, 2013), golf (Couceiro, Martins, Clement, Dias, & Mendes, 2014) and strength training (Novatchkov, & Baca, 2013), in the determination of tactics in football (Papahristodoulou, 2012), for selecting soccer players during the transfer season (Nasiri, Ranjbar, Tavana, Arteaga, & Yazdanparast, 2019), in the detection and measurement of jumps in various sports (Roberts-Thomson, Lokshin & Kuzkin, 2014), and in tennis (Zháněl, Leist, Kadlčíková, & Talašová, 1999). Models have also been published for the prediction of the results of football and basketball matches (Zeng, & Li, 2014; Trawinski, 2010) and the determination of race winners (Pudaruth, Seesaha, & Rambacussing, 2013), as well as models for the identification of sporting talent in Olympic triathlon (Bottoni, Giafelici, Tamburri, & Faina, 2011) and a fuzzy expert system for identifying talented athletes on the basis of morphological measurements and motor tests for use on the internet (Papić, Rogulj, & Pleština, 2008; Papič, Rogulj, & Pleština, 2011). With the Analytic Hierarchy Process (AHP), Saaty (1980) proposed a process for deriving criteria weights with the use of pair-wise comparison. With reference to Saaty (1980), Ahmed and Kilic (2019) analysed the possible use of AHP along with fuzzy set theory, taking into consideration the weights of individual criteria for an overall evaluation. In addition to evaluating the creative work outcomes of Czech art colleges (Stoklasa, Jandová, & Talašová, 2013), for example, Saaty's method has also found broad applications in sport. Singh, Bhatia and Singh (2011) used a "fuzzy cognitive map" using various characteristics of the play (parameters) of both individual players and the whole team to evaluate the performance of cricketers. Use of weighted criteria for the identification of talent in volleyball has been presented by Noori and Sadeghi (2017), while a model for the selection of the most useful badminton players has been proposed by Ağılönü and Balli (2009). It is clear from the synthesis given above that there are a large number of possible applications of fuzzy theory in sport, such as the evaluation of test results, the identification of talent, and the analysis of match statistics.

The study put forward here follows up from previous publications applying fuzzy theory in tennis (Hubáček, Zháněl, & Polách, 2015; Zderčík, Nykodým, Talašová, Holeček, & Bozděch, 2020; Zháněl et al., 1999). The study aims to analyse the possible use of Saaty's method in the evaluation of the level of performance preconditions in tennis and comparison of the results of two approaches to the evaluation of individual criteria: 1) with the use of equal weights, 2) with the use of various weights (based on an expert judgement) derived by Saaty's method.

Methods

The research set was comprised of female Czech tennis players aged 11–12 years (U12) who took part in regular testing in the years 2000–2017 (n = 211, age: 11.97 ± 0.55, height: 154.72 ± 7.26 cm, weight: 43.51 ± 7.28 kg). Research data (physical values and dimensionless quantities) were obtained using the standardised test battery TENDIAG1 (Zháněl et al., 2015) focusing on the diagnostics of somatic and motor preconditions. The test battery contains a total of nine tests divided into three areas: physical preconditions, fitness preconditions and coordination preconditions. Somatic preconditions (height and weight, body mass index, index of flexibility in the shoulder joints) are of an informative nature and are not assigned a point score. The level of fitness preconditions (handgrip strength of the playing hand, running speed with changes of direction and intermittent endurance) and coordination preconditions (the reaction speed of the arms and legs, the flexibility of the torso) was diagnosed by means of motor tests and assigned a point score on a scale of 0 (small) – 1 (medium) – 2 (large). The overall score given by the TENDIAG1 battery is the sum of the points obtained in the fitness and coordination tests (6 tests, sum of points in a range of 0–12; Zháněl et al., 2015). The normality of data distribution was verified by the Kolmogorov-Smirnov test ($p > .20$). The degree of dependence of the two approaches (Pearson's Correlation Efficient r) and the statistical significance or effect size of the differentiation of mean values (Student's t-test or Cohen's d; Cohen, 1988) were also determined. The research data were processed using the software MS Excel and Statistica 12.

For the evaluation of the individual athletes in items of the TENDIAG1 test battery with a fuzzy approach, S-shaped and Z-shaped membership functions were chosen. Two models have been then designed and compared. A model that uses equal weights for all tests (denoted as AM in the following text) was first used in accordance with the aims of the study. Subsequently, the significance of the individual tests was judged by experts and weights for the individual tests were derived from this with the use of Saaty's method (Saaty, 1980, 1990). This way, a second model (denoted as EX in the text below) that uses these expertly set weights was created. The expert judgement was performed by tennis coaches' (B licence, n = 40) with the use of a non-standardised questionnaire as part of their training course. In the first part of the questionnaire, each of the trainers judged the significance to tennis performance of the individual items in the TENDIAG1 test battery (n = 9) by ranking these items from 1st (most important) to 9th (least important) place. In the second part of the questionnaire, the trainers stipulated the intensity of the significance of preferences between each two test items (criteria) using a five-point scale (1, 3, 5, 7, 9; Table 5). The information from this second part of the questionnaire was used for deriving the weights for the individual test items. FuzzME software developed at the Faculty of Science at Palacký University in Olomouc was used for the construction of fuzzy assessment functions and for the calculation of degrees of membership.

Results

Basic statistical characteristics (Table 1) were calculated for individual items on the basis of the results obtained by testing the set of female Czech tennis players aged 11–12 using the TENDIAG1 test battery.

Table 1. Overview of basic statistical characteristics in a set of female tennis players (U12; n = 211)

Test	Item	M	SD	Min	Max
A	Age	11.97	0.55	11.00	12.90
H	Height	154.72	7.26	135.50	181.00
W	Weight	43.51	7.28	28.00	66.80
BMI	Body mass index	18.08	2.05	13.60	24.49
T1	Handgrip strength	23.27	4.68	12.40	43.30
T2	Speed (running)	15.31	0.86	13.51	17.84
T3	Endurance (intermittent)	157.36	8.85	137.51	188.90
T4	Flexibility of torso	39.99	3.76	30.00	50.00
T5	Reaction speed of arms	0.55	0.06	0.42	0.68
T6	Reaction speed of legs	0.43	0.05	0.32	0.68

Legend: M – mean, SD – standard deviation, Min – minimum value, Max – maximum value

Fuzzy evaluation

S-shaped and Z-shaped membership functions were selected for the individual TENDIAG1 items (tests) (Table 2). An S-shaped function was selected for tests in which an increasing numerical value means higher sports performance (strength of playing hand, flexibility of torso). A Z-shaped function was selected for tests in which a falling numerical value means higher sports performance (running speed, intermittent endurance, arm reaction speed, leg reaction speed). Both functions have two tipping points between which an interval of medium performance level is found. The anchor of extreme points on the interval of the medium level was selected with reference to the study by Hubáček et al. (2015).

Table 2. Overview of membership functions for scored tests and normative values (M ± SD)

Test	MF type	Medium level
T1	S	18.59–27.95
T2	Z	14.45–16.17
T3	Z	148.51–166.21
T4	S	36.23–43.75
T5	Z	0.49–0.61
T6	Z	0.38–0.48

Legend: MF – membership function

A membership function value within an interval of [0; 1] is assigned to test results falling within a medium level interval. A value of 0 (or 1) is assigned to results that are lower than the lower limit of the medium level interval for the S-shaped (Z-shaped) function. A value of 1 (or 0) is assigned to results that are higher than the upper limit of the medium level interval for the S-shaped (Z-shaped) function.

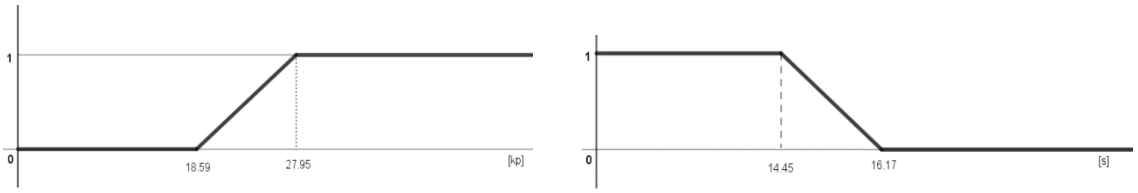

Figure 1. An example of the construction of an S-shaped membership function (left, strength) and Z-shaped membership function (right, speed)

FuzzME software was used for the evaluation of the results. In this software, a so-called goals tree was designed. The main node of the tree represents the overall evaluation of the athlete. This node was comprised of six sub-nodes that represent the individual tests in the TENDIAG1 test battery. The corresponding type of membership function was selected for each sub-node and the medium level was set. Then, the individual test results for all probands were imported into FuzzME software. The software used the selected membership functions to assign the corresponding evaluation (value from 0 to 1) for each of the test results (Table 3). The overall evaluation for each proband was then calculated as a weighted average of evaluations of the individual tests.

Table 3. Example of the evaluation of the results of individual tests by FuzzME software for selected athletes

Athletes	T1	T2	T3	T4	T5	T6
1	0	0.099	0	0.102	0	0.300
2	0.482	0.680	0	1	0	0.100
…	…	…	….	…	…	…
210	1	1	1	1	1	0.500
211	1	1	1	0.235	0.667	0.500

For example, Athlete No. 1, received the evaluation 0 in three tests on a scale [0; 1], which means a small level of performance, while Athlete No. 210 received the evaluation 1 in five tests, which means a large level of performance.

Weights of criteria

As mentioned in the previous section, a weighted average was used for aggregating the evaluation of the individual tests into the overall evaluation of the athlete. For this task, it was necessary to set weights for the individual tests. Two alternative approaches were studied. The first one uses equal weights for all tests while the latter one uses expertly set weights, which also take into account the various importance of the individual criteria.

First, equal weights (AM) were used for all the tests, i.e. normed weights whose sum is 1. For the evaluation of a total of six tests, the weights of the individual tests were 1/6 (0.16666667).

Next, Saaty's method (Saaty, 1980) was used for deriving weights (EX) that takes into account the experts' opinions on the various importance of individual tests in the TENDIAG1 test battery. As the first step, the individual scored items in the test battery (n = 6) were ranked according to significance from most important (1) to least important (9). As the second step, it was necessary to assess the intensity of significance between each pair of criteria (j and k), leading to a matrix of intensities of preferences S with their elements sjk (j, k = 1, ..., 6) expressing the relative significance of the j-th criterion in respect of the k-th criterion as adjudged by experts. In agreement with the authors Ağılönü and Balli (2009) a five-point scale (1, 3, 5, 7, 9) accompanied by a verbal description was used for the assessment of the intensity of preferences (Table 4).

Table 4. Verbal assessment of the five-point scale

	1	both criteria are equally important
	3	j-th criterion is weakly more important than k-th
s_{jk}	5	j-th criterion is strongly more important than k-th
	7	j-th criterion is demonstratedly more important than k-th
	9	j-th criterion absolutely more important than k-th

The results of the first part of the questionnaire in which tennis trainers (experts) assessed the individual scored items in the TENDIAG1 test battery (T1–T6) according to significance from the most important (1) to the least important (9) showed (Table 5) that these trainers consider the most important tests to be the reaction speed of the legs (1.72) and the reaction speed of the arms (2.85). Of the group of less important tests (T1–T4) the test of endurance (5.93) and the test of flexibility of the torso (5.20) were assessed as the least important, though the tests of strength (5.10) and speed (5.05) received a similar assessment.

Table 5. Expert judgement of the significance of individual TENDIAG1 scored tests

Item	Ranking									WM
	1	2	3	4	5	6	7	8	9	
T1	4	0	7	5	7	4	7	3	3	5.10
T2	2	7	1	6	4	5	8	2	3	5.05
T3	1	2	6	1	6	5	9	3	7	5.93
T4	2	3	3	7	9	5	3	5	3	5.20
T5	10	14	6	0	6	1	2	1	0	2.85
T6	20	15	2	1	0	0	1	0	0	1.72

Legend: WM – weighted mean

In the next step, the tennis trainers were asked to judge the mutual relationships between the individual items in the TENDIAG1 test battery, i.e. to determine how much more important one battery item (tests T1–T6) is to tennis performance than another. The resultant intensities of preferences were calculated from the values obtained by Saaty's method (specifically, its variant that uses a geometric mean instead of the eigenvector was used). The resultant matrix S is depicted in Table 6.

The maximum eigenvalue for matrix S is $\lambda = 6.178$. This corresponds to the Consistency Ratio (CR) = 0.029 that was calculated for validating the consistency of the experts' judgments in line with the principles of Saaty's method. Because the CR is lower than the threshold proposed by Saaty (0.1), the matrix is consistent enough and can be used for derivation of weights.

Table 6. Matrix S of intensities of preferences of individual TENDIAG1 scored tests

Test	T6	T2	T5	T4	T3	T1
T6	1	1	3	3	5	7
T2	1	1	1	3	5	5
T5	1/3	1	1	3	5	5
T4	1/3	1/3	1/3	1	3	3
T3	1/5	1/5	1/5	1/3	1	1
T1	1/7	1/5	1/5	1/3	1	1

The expertly judged weights of the individual assessed items in the TENDIAG1 test battery obtained from the resultant matrix by means of Saaty's method are given in Table 7 along with a comparison to the equal criteria weights. The difference between the equal weights set by the arithmetic mean (AM) and the expertly judged weights (EX) is given in the column difference (DIF). A positive difference was found for three items (T1 = strength, T3 = endurance, T4 = flexibility of torso), i.e. the test weight with the use of equal weights (AM) is higher than the expertly judged weight (EX). A negative difference was found for the three other items (T2 = speed, T5 = reaction of arms, T6 = reaction of legs), which means that the test weight stipulated by the experts (EX) is higher than that obtained with the use of equal weights.

Table 7. Weights of individual tests determined by means of the arithmetic mean and Saaty's method

Test	AM	EX	DIF
T1	1/6	0.044	0.123
T2	1/6	0.259	-0.092
T3	1/6	0.047	0.120
T4	1/6	0.105	0.062
T5	1/6	0.216	-0.049
T6	1/6	0.329	-0.162
Total	1.000	1.000	

Legend: AM – equal weights determined by arithmetic mean; EX – weights determined by Saaty's method; DIF – difference (AM – EX)

A comparison of the overall evaluation

An example of the overall evaluation for selected probands is given in Table 8. The table contains the overall evaluation of the athletes for the approach where equal weights (AM) were used, and for the approach where expertly judged weights (EX) where used. The difference between the results obtained with the use of AM and EX may be either negative (No. 1), which detects a better overall proband evaluation with the use of expertly judged weights than with equal weights, or positive (No. 2), which means that the overall proband evaluation with the use of equal weights is larger than with the use of expertly judged weights.

Table 8. Example of the results of assessment of selected athletes with the use of two studied sets of weights (AM and EX)

Athletes	AM	EX	Difference
1	0.084	0.135	-0.051
2	0.377	0.335	0.042
…	…	…	…
210	0.917	0.836	0.081
211	0.734	0.683	0.051
M ± SD	0.52 ± 0.23	0.53 ± 0.25	$d = 0.04$
r	0.94		$p \leq 0.05$

The results of the assessment of all athletes (n = 211) in the way given in Table 8, i.e. with the use of equal weights for individual tests (AM) or with expertly judged weights (EX), were compared in respect of the degree of dependence (Pearson's correlation efficient r) and from the viewpoint of the difference of mean values (Student's t-test or Cohen's d).

The correlation ($r = 0.94$) between the assessment results obtained with equal (AM) and expertly judged (EX) weights in a set of female tennis players aged 11–12 ($n = 211$) can be evaluated as a great power of association both from the viewpoint of statistical significance ($p \leq 0.05$) and from the viewpoint of effect size (ES, large). Assessment of the statistical significance of the difference of mean values between the results obtained by the two methods of determining weights did not demonstrate significant differences ($p > 0.05$), as was also the case for assessment of effect size by Cohen's d ($d = 0.04$). It can then be said that the results of the overall evaluation by means of the approach with equal weights and expertly judged weights did not differ significantly.

Discussion

The Analytic Hierarchy Process (AHP; Saaty, 1980) has been used in a number of publications about sport in recent years. The study put forward here presents a comparison of the results of evaluation using equal weights and expertly judged weights obtained by Saaty's method (Saaty, 1980, 1990). While we judged the importance of six criteria (assessed TENDIAG1 tests) in a set of female tennis players in our study, the cited authors have used widely differing numbers of criteria in various sports (Budak, Kary & Tansel, 2017, volleyball: 5 criteria; Ağılönü & Bali, 2009, badminton: 13 criteria; Durović, Dizdar & Zagorac, 2015, tennis: 8 criteria; Ozceylan, 2016, soccer: 20 criteria; Ahamada, Naqvi & Bega, 2013, cricket: 28 criteria) selected with a view to the goal of their research and the nature of the given sport. In each of the studies given above, the authors demonstrated a certain level of accuracy of the model, meaning there is no unambiguous reason for preferring a larger or smaller number of evaluation criteria. A smaller number of criteria is clearly more suitable for trainers for practical purposes and to simplify the process of assessing athletes. The evaluating criteria in the study presented here are of the nature of motor tests (fitness and coordination), in contrast to studies focusing, for example, on the assessment of playing skills, morphological characteristics or character traits. An example of this approach can be found in studies assessing the standard of playing activities in volleyball, e.g. serve, reception, block, attack, pass (Budak et al., 2017), or assessment of the standard of playing skills in tennis divided into offence (e.g. level of offensive forehand) and defence (e.g. level of first serve return), as given by Durovič et al. (2015). Ozceylan (2016) used a combination of motor abilities (strength), skills (passing) and character attributes (leadership) in soccer, while Ağılönü and Bali (2009) constructed a set of criteria in badminton from motor abilities (reaction time), skills (drop shot) and morphological characteristics (height). Our assessment of the significance of individual items in the TENDIAG1 test battery (T1–T6) to tennis performance brought rather surprising results. The trainers considered the most important test to be the test of reaction speed of the legs and ranked the other tests according to importance (from the most important to the least important) as follows: the reaction speed of the arms, speed, strength, flexibility of torso, endurance. This evaluation may be rather at odds with the findings made by various authors relating to the importance of the fitness factor – in particular strength and speed – to sports performance in professional tennis (Ferrauti et al., 2014; Filipčič et al., 2005; Schönborn, 2010; Zháněl et al., 2015), though it is evidently justified for the age category U12 (female players), in which the emphasis in the training process is placed, first and foremost, on developing technique and coordination. Nevertheless, the ideas resulting from the given studies in terms of expansion to the structure or number of assessment criteria may provide motivation for the further direction of the research.

In the study presented here, the most important criterion was considered the reaction speed of the legs (weight 0.329) on the basis of the results of Saaty's method (Table 7) followed (ranked from most important to least important) by the criteria running speed (weight 0.259), the reaction speed of the arms (weight 0.216), the flexibility of the torso (0.105), endurance (0.047) and strength (0.044). Similarly, Ağılönü and Bali (2009) identified reaction speed (weight 0.133), flexibility (weight 0.102) and leg power (weight 0.118) as the most important of 13 criteria in badminton players (n = 12, age 9–11).

The results of comparison of fuzzy evaluation with the use of equal criteria weights and expertly judged criteria weights demonstrated a high degree of association between the two approaches; evaluation of the significance of the difference of mean values did not demonstrate significant differences. Nevertheless, the assessment obtained with the use of expertly judged criteria weights offers trainers a broader, more accurate and finer scale for the assessment of the strengths and weakness of athletes and the opportunity of drawing up an optimal training plan for the improvement of sports performance and long-term performance on this basis.

Conclusions

The aim of this study was to analyse the possible use of Saaty's method in the evaluation of the level of performance preconditions in tennis and comparison of evaluation results obtained with the use of equal weights and the results obtained with (various) weights based on an expert judgement. The method of fuzzy assessment of individual criteria (six TENDIAG1 tests) was based on normative values; the choice of S-shaped and Z-shaped membership functions was made on the basis of evaluation of the character of the individual criteria. Tennis coaches' (n = 45) performed the expert evaluation of the importance of the individual criteria (tests T1–T6) to tennis performance and their weights were determined with the use of Saaty's method. The results of the individual athletes (female tennis players, U12, n = 211) were assessed by means of equal and expertly judged criteria weights. It can be stated on the basis of the results of Saaty's method that tennis trainers consider the reaction speed of the legs and running speed the most important criteria for tennis performance in the U12 age category, while they placed the least importance on endurance and strength. Although a high degree of association was demonstrated between the results obtained with the use of equal weights and the results obtained with differing weights, and the differences in the mean values were insignificant, the evaluation obtained with the use of expertly judged criteria weights offers trainers a broader, more accurate and finer scale for the assessment of the performance preconditions of athletes. The results and the methodology of comparable studies provide motivation for the further direction of research to expand the structure and number of evaluation criteria.

Ethics statement

The Research Ethics Committee of Masaryk University has reviewed the application to conduct the research project MUNI/A/1087/2017 and on 21. 12. 2017 the Committee approved this project to be conducted.

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