Testing some common tennis hypotheses:

Four years at Wimbledon[1]

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Abstract

In this paper we investigate the truth (more often the untruth) of seventeen commonly heard statements about tennis. We base our analysis on point-by-point data of almost 500 singles matches played at Wimbledon, 1992-1995. The seventeen hypotheses under consideration are:

1 A player is as good as his/her second service;
2 There exists a psychological advantage to serve first in a set;
3 Few breaks occur during the first few games in a match;
4 Serving with new balls provides a slight advantage;
5 In the 1995 Wimbledon Championships softer balls were used than in previous years. This has resulted in less service dominance;
6 After a double fault most players make sure their next first service is in;
7 An ace is worth more than one point;
8 Good players make sure their first service is in at game point or break point;
9 The real champions play their best tennis at the big points;
10 The 7th game is the most important game in the set;
11 All points are equally important;
12 After breaking your opponent's service there is an increased chance that you will loose your own service;
13 After missing break points in the previous game there is an increased chance that you will loose your own service;
14 After winning a set there is an increased chance that you will loose the first game in the next set;
15 One break is enough to win the set;
16 In long matches the dominance of the service decreases;
17 In the final set the player who has won the previous set has the advantage.

1 Introduction

The All England Croquet Club was founded in the Summer of 1868. Lawn tennis was first played at The Club in 1875, when one lawn was set aside for this purpose. In 1877 The Club was re-titled The All England Croquet and Lawn Tennis Club and the first tennis championship was held in July of that year. Twenty-two players entered the event which consisted of men's singles only. Spencer Gore became the first champion and won 12 guineas and the Silver Challenge Cup. In 1884 the ladies' singles event was held for the first time. Thirteen players entered this competition and Maud Watson became the first ladies' champion receiving 20 guineas and a silver flower basket. (William Renshaw, the 1884 men's singles champion received 30 guineas and the Challenge Cup.) In 1922 The Championships moved from Worple Road to its current location at Church Road.[2] For more than a century The Championships at Wimbledon have been the most important event on the tennis calender. Currently both the men's singles (MS) and the ladies' singles (LS) event are restricted to 128 players of which 16 are seeded.

Because of television broadcasts, tennis has become a sport which is viewed by millions all over the world. Many have ideas about tennis. In particular, most commentators hold strong ideas about, for instance, the advantage of serving first in a set, the advantage of serving with new balls, and the special ability of top players to perform well at the "big" points. In this paper we shall investigate the truth (or more often the falsity) of seventeen such hypotheses.[3] The hypotheses under consideration are:

1. A player is as good as his/her second service;
2. There exists a psychological advantage to serve first in a set;
3. Few breaks occur during the first few games in a match;
4. Serving with new balls provides a slight advantage;
5. In the 1995 Wimbledon Championships softer balls were used than in previous years. This has resulted in less service dominance;
6. After a double fault most players make sure their next first service is in;
7. An ace is worth more than one point;
8. Good players make sure their first service is in at game point or break point;
9. The real champions play their best tennis at the big points;
10. The 7th game is the most important game in the set;
11. All points are equally important;
12. After breaking your opponent's service there is an increased chance that you will loose your own service;
13. After missing break points in the previous game there is an increased chance that you will loose your own service;

[2] See Riddle (1988) and Little (1995) for some historical details.

[3] Magnus and Klaassen (1996) considered three of the seventeen hypotheses in a preliminary analysis.

14 After winning a set there is an increased chance that you will loose the first game in the next set;
15 One break is enough to win the set;
16 In long matches the dominance of the service decreases;
17 In the final set the player who has won the previous set has the advantage.

A match at Wimbledon in the men's singles lasts, say, two-and-a-half hours. The effective time-in-play for one point is about 5 seconds. With 6 points per game, a game lasts 30 seconds. With 10 games per set, a set lasts 5 minutes. With 4 sets per match, a match lasts only 20 minutes. The remaining two hours and ten minutes are to be filled by the commentators. It follows that they play a major part in the broadcast. But are the *idées reçues* of the commentators correct? This is what we shall find out in this paper.

In Section 2 we discuss the data and test Hypothesis 1. Section 3 deals with the advantage, if any, of serving first in a set (Hypotheses 2 and 3). Section 4 discusses the effect of (new) balls (Hypotheses 4 and 5). "Big points" are under investigation in Section 5 (Hypotheses 6-11), breaks in Section 6 (Hypotheses 12-15), and the final set in Section 7 (Hypotheses 16 and 17).

2 88,883 points played at Wimbledon

Due to the courtesy of IBM UK we have data on 481 matches played in the men's singles and ladies' singles championships at Wimbledon from 1992 to 1995. This accounts for almost one half (481/1,016) of all singles matches played during these four years. For each of these matches we know the exact sequence of points. We also know at each point whether the first or the second service was in and whether the point was decided through an ace or double fault. In Table 1 we provide a summary of the data.

Number of ...	MS	LS
Matches	258	223
Sets	950	503
Games	9,367	4,486
Points	59,466	29,417
Sets / match	3.68	2.26
Games / set	9.86	8.92
Points / game	6.35	6.56

Table 1 - Number of matches, sets, games and points in the data set.

We have slightly more matches for men than for women, but of course many more sets, games and points for the men's singles than for the ladies' singles, because the men play for three won sets and the women for two. The men play less points per game than the women, because the dominance of their service is greater. But the women play less games per set on average (scores like 6-0 and 6-1 are more common in the ladies' singles than in the men's singles), because the difference between the seeded and the non-seeded players is much greater. Both men and women play about 60 points per set. The men play on average 230 points per match, the women 132.

All matches in our data set are played on one of the five "show courts". The show courts are Centre Court and Courts 1, 2, 13 and 14. This causes an overrepresentation of matches in which seeded players are involved. In reality, both in the men's singles and in the ladies' singles, 508 matches were played over the four years. In the men's singles, 27 matches were played between two seeded players (26 in our data set), 184 between a seed and a non-seed (158 in our data set) and 297 between two non-seeded players (only 74 in our data set). In the ladies' singles, 30 matches were played between two seeds (29 in our data set), 197 between a seed and a non-seed (152 in our data set) and 281 between two non-seeds (only 42 in our data set). This shows that matches between two non-seeded players are seriously underrepresented in our data set. For example, of the 152 first-round matches over four years between two non-seeded players, only

34 (22%) were played on one of the show courts in the men's singles and only 24 (16%) in the ladies' singles.

In order to account for this selection problem and avoid too much averaging, we shall usually distinguish between the 16 seeded players and the others, the non-seeded players. Tables 2A and 2B provide information about the number of matches (and sets) of seeded against seeded (Sd-Sd), seeded against non-seeded (Sd-NSd), and non-seeded against non-seeded (NSd-NSd) players.

Set	Sd-Sd	Sd-NSd	NSd-NSd	Total
1	26	158	74	258
2	26	158	74	258
3	26	158	74	258
4	17	75	33	125
5	9	27	15	51
Total	104	576	270	950

Table 2A - Division of sets over seeded and non-seeded players: men’s singles.

Set	Sd-Sd	Sd-NSd	NSd-NSd	Total
1	29	152	42	223
2	29	152	42	223
3	9	36	12	57
Total	67	340	96	503

Table 2B - Division of sets over seeded and non-seeded players: ladies’ singles.

Taking men's singles and ladies' singles together, the majority of the matches in our data set (about 64%) are between a seeded and a non-seeded player, about 24% are matches between two non-seeded players, and only 11% between two seeded players. A final deciding set (fifth set for the men, third set for the ladies) is played in 20% of the men's singles and 26% of the ladies' singles.

The service is one of the most important aspects of tennis, particularly at Wimbledon. In Tables 3A and 3B we provide some of its characteristics. In these and subsequent tables, Sd-NSd indicates a match of a seeded (Sd) against a non-seeded (NSd) player. The first player (Sd) is serving and the second player (NSd) receiving. Sd-Sd, NSd-Sd and NSd-NSd are similarly defined.

Percentage of ...	Sd-Sd	Sd-NSd	NSd-Sd	NSd-NSd	Total
Aces	11.8	11.1	7.7	7.5	9.1
Double faults	5.1	5.1	5.8	5.6	5.5
Points won on service	67.1	69.3	61.2	64.0	65.0
1st services in	58.7	59.5	59.6	59.8	59.5
2nd services in	87.8	87.3	85.7	86.1	86.5
Points won if 1st service in	77.8	78.2	70.3	72.7	74.2
Points won if 2nd service in	59.1	64.4	55.6	59.1	59.6
Points won on 1st service	45.7	46.5	41.9	43.5	44.1
Points won on 2nd service	51.8	56.2	47.7	50.9	51.6
Games won on service	86.1	89.0	74.4	80.4	81.8

Table 3A - Service characteristics: men’s singles.

Percentage of ...	Sd-Sd	Sd-NSd	NSd-Sd	NSd-NSd	Total
Aces	3.2	4.2	2.5	3.0	3.3
Double faults	3.8	4.2	5.8	6.0	5.0
Points won on service	56.9	62.9	50.2	56.3	56.4
1st services in	65.6	61.6	60.6	59.8	61.5
2nd services in	88.8	89.2	85.2	85.0	86.9
Points won if 1st service in	62.5	69.6	56.4	63.0	62.8
Points won if 2nd service in	51.9	58.5	47.7	54.4	53.1
Points won on 1st service	41.0	42.8	34.2	37.7	38.6
Points won on 2nd service	46.1	52.1	40.6	46.2	46.1
Games won on service	66.6	77.6	49.8	64.3	64.3

Table 3B - Service characteristics: ladies’ singles.

We see that the men serve almost three times as many aces as the ladies, but serve about the same number of double faults: 5.5% in the men's singles, 5.0% in the ladies' singles.[4]

In understanding the other service characteristics in Tables 3A and 3B, the difference between "points won if 1st (2nd) service in" and "points won on 1st (2nd) service" is important. In the men's singles, when two seeds play against each other, the 1st service is in 58.7% of the time. If the 1st service is in, the probability of winning the point is 77.8%. Therefore, in the men’s singles the probability of winning the point on the

[4] The percentage of aces is defined as the ratio of the number of aces (first or second service) to the number of points served (rather than to the number of services).

1st service is 0.587 * 0.778 = 0.457; see column 1 of Table 3A. Hence,

(1) %points won on 1st service = (%points won if 1st service in) * (%1st services in)

and, of course, the same for the 2nd service.[5]

The probability of winning a *point* on service is 65.0% (MS) and 56.4% (LS), respectively. The difference is 8.6%-points with a standard error of 0.35%.[6] The dominance of the service at point level is thus significantly larger in the men's singles than the ladies' singles, just as one would expect.[7] The service advantage is brought out even stronger when we calculate the probability of winning a service *game*, which is 81.8% (MS) and 64.3% (LS).[8] Hence, the service dominance at game level is 17.5%-points (0.82%) larger in the men's singles than in the ladies' singles. This significant difference makes the men's singles a very different game from the ladies' singles.

The percentages of first and second services in are remarkably similar for the men and the ladies: 59.5% (MS) versus 61.5% (LS) for the first service and 86.5% (MS) versus 86.9% (LS) for the second service. However, the percentages of first services in are significantly different, whereas the percentages of second services in are not. Since the service-in percentage is something the player can control (he/she could serve 100% first services in, but of course the quality of the first service would suffer), the question can be raised whether the observed percentages reflect the best strategy. If a player knows the optimal service-in percentages against a particular opponent, he/she could try and achieve these during the match. The question of optimal service-in percentages, which has potential consequences for coaching and strategy, will be taken up in a subsequent paper.

Another question of interest, and one which can be answered with the available data, is what would happen if the rules were changed and only one service was allowed rather than two. This suggestion is one of many currently under discussion, all of which aim at decreasing the dominance of the service, thereby, it is hoped, making tennis more attractive for the spectator. If a player has only one service, this will be his/her current second service. After all, a player having only one service can be seen as equivalent to a player having two services who has missed his/her first service. The probability of winning a point then becomes 51.6% (MS) and 46.1% (LS).[9] The consequence of this change of rule would thus be that the service

[5] Combining 1st and 2nd service, we also have %points won on service = %points won on 1st service + (% 1st service not in) * (%points won on 2nd service). For example, from Table 3A, first column, 0.671 = 0.457 + (1.0 - 0.587)*0.518.

[6] From now on, if standard errors are reported, they will be displayed in brackets. Thus, 8.6% (0.35%) indicates an estimate of 8.6% with a standard error of 0.35%.

[7] In this paper "significant" means that the estimate is more than 2 standard errors away from its target. For example, 8.6 ±2 standard errors gives an interval (7.9, 9.3) which does not include 0 and hence we conclude that the true unknown probabilities are different.

[8] This is what Alefeld (1984) calls the *Verstärkungseffekt*: any advantage at point level is amplified at game level.

[9] In both percentages we abstract from selection effects that are caused by the overrepresentation of players with a risky first service or players that are in a bad shape. Furthermore, under the new rule of one-service-only, if a player decides always to use his/her old first (rather than second) service, the probability of winning a point on service is only 44.1% (MS) and 38.6% (LS).

dominance becomes very much smaller. In the ladies' singles the service advantage would even turn into a service disadvantage!

Tables 3A and 3B make it possible to test our first hypothesis.

Hypothesis 1: A player is as good as his/her second service.

How should we measure the quality of the 2nd service? Clearly not by the %2nd services in, because this tells us nothing about the difficulty of the service. Neither by the %points won if 2nd service in, because this tells us nothing about how often the 2nd service is in. The most appropriate measure for the quality of the 2nd service is a combination of the two, viz. the %points won on 2nd service as given in formula (1) (with 1st service replaced by 2nd service). Ironically, television broadcasts inform us about %2nd services in and sometimes about %points won if 2nd service in, but never about %points won on 2nd service.

In the men's singles, let us compare the matches Sd-Sd and NSd-NSd; see columns 1 and 4 in Table 3A. With some simplification, the players in these matches can be considered to have the same strength: they are either both good (NSd-NSd) or both very good (Sd-Sd). We see that the seeds win significantly more points on 1st service than the non-seeds (45.7% > 43.5%), but that the estimated probabilities of winning points on 2nd service are not significantly different. Hence a seeded player distinguishes himself from a non-seeded player by having a better 1st service and not by having a better 2nd service. Therefore, Hypothesis 1 is not supported by the Wimbledon data. The same is true in the ladies' singles as can be verified from Table 3B.

There is, however, one important difference between the men's singles and the ladies' singles and this relates to the quality of the 1st service. Referring to formula (1), the quality of the 1st service is made up from two components: %points won if 1st service in and %1st services in. In the men's singles the difference in the quality of the 1st service between seeded and non-seeded players is determined primarily by the %points won if 1st service in (77.8% is significantly larger than 72.7%), while the difference in %1st services in is not significant. In the ladies' singles the difference is determined primarily by the %1st services in (65.6% is significantly larger than 59.8%), while the difference in the %points won if 1st service in is insignificant.

After this preliminary discussion of the data, let us now discuss sixteen further ideas that are commonly heard about tennis and analyse whether the Wimbledon data support these ideas or not. The discussion of the remaining sixteen hypotheses is organised in five groups: serving first, new balls, big points, breaks, and the final set.

3 Serving first

Most players, when winning the toss, select to serve. Is this a wise strategy? This depends on whether or not you believe our second hypothesis.

Hypothesis 2: There exists a psychological advantage to serve first in a set.

The reason for the advantage, if it exists, would be that the player who receives in the first game is usually one game behind and that this would create extra stress. Let us investigate whether there is any truth in this hypothesis.

Our first calculations seem to indicate that Hypothesis 2 must be wrong. Overall only 48.3% of the sets played in the men's singles are won by the player who begins to serve in the set. In the ladies' singles the percentage is even lower: 47.5%. The standard errors of the two estimates are 1.6% and 2.2%, respectively. Therefore, neither of the two percentages is significantly different from 50%, but, if anything, starting to serve would appear to be an disadvantage rather than an advantage. If we look at the sets separately, then we see that this finding (starting to serve is a disadvantage rather than an advantage) seems to be true in every set, except the first. In the men's singles the estimated probability of winning a set when starting to serve is 54.7% in the first set and 45.0%, 45.0%, 48.8% and 49.0% in the second to fifth sets, respectively. Thus, all estimated probabilities are less than 50%, except for the first set.

Exactly the same phenomenon occurs in the ladies' singles. There the probability that the player who starts to serve also wins the set is estimated to be 51.1% in the first set, 45.3% in the second set and 42.1% in the third set. Therefore, if there is any truth in Hypothesis 2, it would seem to be only in the first set.

However, in analysing this hypothesis, we need to realise that the player who starts to serve in a set (if it is not the first set) is usually the weaker player. This is so, because of a combination of two factors. First, it is likely that the stronger of the two players won the previous set. Secondly, it is more likely that the last game of the previous set is won by the server of that game than by the receiver, so that a set is won by serving for the set and winning the game, in which case the looser of the set begins to serve in the next set. Hence, in all sets except the first, the above percentages are less than 50% not because there is a disadvantage for the player who serves first in a set, but more likely because the server in the first game is usually the weaker player. A proper analysis of Hypothesis 2 should take this into account. Hence, in Table 4A we consider a player in the men's singles *who has won the previous set* and compare the estimated probability that he wins the current set when starting to serve with the estimated probability that he wins the current set when his opponent starts to serve.

Set	Sd-Sd S	Sd-Sd R	Sd-NSd S	Sd-NSd R	NSd-Sd S	NSd-Sd R	NSd-NSd S	NSd-NSd R	Total S	Total R
1	46.2	53.8	80.7	78.6	21.4	19.3	58.1	41.9	54.7	45.3
2	60.0	52.4	82.9	78.8	16.7	30.8	68.0	69.4	71.4	66.3
3	80.0	75.0	72.7	76.3	66.7	40.9	77.3	71.2	73.9	70.0
4	20.0	50.0	73.3	70.0	26.3	33.3	70.6	62.5	51.8	53.6
5	0.0	12.5	66.7	85.7	25.0	38.5	50.0	71.4	43.8	48.6

Table 4A - Estimated probabilities of winning a set after winning previous set: men's singles. S: starts serving; R: starts receiving.

For example, if a seeded (Sd) player has won the first set against a non-seeded (NSd) player, then his probability of winning the second set is estimated as 82.9% when he (the seeded player) begins to serve and as 78.8% when his opponent begins to serve. Of course, there is no set previous to the first and hence the probabilities in the first row are simply the (unconditional) probabilities of winning the first set. The same probabilities, estimated for the ladies' singles, are provided in Table 4B.

Set	Sd-Sd S	Sd-Sd R	Sd-NSd S	Sd-NSd R	NSd-Sd S	NSd-Sd R	NSd-NSd S	NSd-NSd R	Total S	Total R
1	62.1	37.9	71.8	83.8	16.2	28.2	66.7	33.3	51.1	48.9
2	63.6	72.2	88.0	89.7	30.8	33.3	70.0	72.7	73.4	75.2
3	40.0	25.0	70.0	84.6	0.0	14.3	75.0	87.5	48.0	62.5

Table 4B - Estimated probabilities of winning a set after winning previous set: ladies' singles. S: starts serving; R: starts receiving.

Let us consider the first three sets in the men's singles and the first two sets in the ladies' singles, because the other sets have relatively few observations and hence large standard errors.[10] There is some indication that in the men's singles there is an advantage in serving first and hence that Hypothesis 2 is true: the overall probability of winning a set after winning the previous set is higher for the player who begins to serve than for the player who begins to receive. The difference is 9.4%-points (6.2%) in the first set, 5.1%-points (6.2%) in the second set and 3.9%-points (5.9%) in the third set. These results are not significant

[10] Moreover, in sets 4 and 5 in the men's singles and set 3 in the ladies' singles one would expect the players to be more equally matched than in the earlier sets. This is reflected in Tables 4A and 4B; see also Tables 13, 17A and 17B. Comparison between sets 1-3 and sets 4-5 in the men's singles (and equally between sets 1-2 and set 3 in the ladies' singles) is complicated by this "selection effect".

and the differences are not positive for all four sub-categories (Sd-Sd, Sd-NSd, etcetera), but they do give some support to the hypothesis, especially in the first set.

In the ladies' singles there is no such support. The probability of winning the first set is higher, but not significantly so, for the player who begins to serve than for the player who begins to receive (the difference is 2.2%-points with a standard error of 6.7%), but the probability of winning the second set after winning the first is lower, again not significantly so, for the player who begins to serve than for the player who begins to receive (the difference is 1.8%-points with a standard error of 5.9%). Hence in the ladies' singles no conclusion can be drawn from the data either in favour or against Hypothesis 2.

There is only one result that seems to be reasonably robust and that is that in the first set of a match there is an advantage in serving first. But why should the first set be different from the other sets? Maybe this is because fewer breaks occur in the first few games of a match.

Hypothesis 3: Few breaks occur during the first few games in a match.

The idea behind this *idée reçue* is the following. Suppose your opponent begins to serve. In the first game you are not under much pressure to break your opponent's service. Instead you use this game (and possibly his/her second service game as well) to read your opponent's strategy, get a feeling for his/her strengths and weaknesses and settle down. In fact, this may be a good strategy. But is it? Hypothesis 3 can be examined using Table 5.

		Sd-Sd	Sd-NSd	NSd-Sd	NSd-NSd	Total
MS	1st game in match	96.2	92.0	74.3	89.2	86.8
	2nd game in match	80.8	87.1	73.9	85.1	81.4
	1st set	90.3	90.3	74.2	82.8	83.4
	Match	86.1	89.0	74.4	80.4	81.8
LS	1st game in match	72.4	84.6	55.4	71.4	70.9
	2nd game in match	62.1	71.6	51.3	66.7	62.3
	1st set	68.4	77.3	51.6	66.4	65.4
	Match	66.6	77.6	49.8	64.3	64.3

Table 5 - Estimated probabilities of winning a service game.

The overall probability of winning a service game is 81.8% (0.4%) in the men's singles and 64.3% (0.7%) in the ladies' singles. The probability of winning a service game in the first set is higher, namely 83.4% (0.7%) in the men's singles and 65.4% (1.1%) in the ladies' singles. The reason why the probability in the first set is higher is entirely due to the effect of the first game in the match. The probability that the server wins the first game is 86.8% (2.1%) in the men's singles and 70.9% (3.0%) in the ladies' singles. This is 5.0 percentage points higher than the match average in the men's singles and 6.6 percentage points higher in the ladies' singles. The standard errors of these differences are 2.1% and 3.1%, respectively, and hence both results are statistically significant. This "first game effect" exists only in the very first game of the match. In the second game it has already disappeared. Hypothesis 3 thus appears to be true, but only for the very first game.

Our conclusion is that, in general, serving first in a set may provide a slight advantage in the men’s singles, but not in the ladies’ singles. However, in the first set there appears to be an advantage in serving first. The reason for this advantage can be completely accounted for by the "first game effect": fewer breaks occur in the first game of the match. This effect exists both in the men's singles and in the ladies' singles. Because of the "first game effect" it is advisable for most players to select to serve when they win the toss.

4 New balls

Tennis as a game has a long history which goes back to the Greeks and Romans. But it was not until 1870 that it became technically possible to produce rubber balls which bounce well on grass. Since then the quality of the tennis balls has gradually improved. Amateurs happily play two or three matches with three balls. The professionals, however, are more demanding. At all professional tournaments six new balls are provided after the first 7 games (to allow for the preliminary warm-up) and then after every 9 games. All commentators and many spectators believe that new balls are an advantage to the server. But is this true? And, if so, what does the advantage consist of?

Hypothesis 4: Serving with new balls provides a slight advantage.

Let us consider Table 6.

	Percentage of ...	1	2	3	4	5	6	7	8	9	Total
MS	Aces	10.0	8.9	9.1	8.9	9.1	9.1	8.9	9.4	8.5	9.1
	Double faults	5.9	5.4	5.8	5.9	5.3	5.5	5.1	4.9	5.1	5.5
	1st services in	58.6	59.3	58.5	58.9	59.0	59.9	60.3	60.3	60.9	59.5
	Games won on service	83.3	82.3	81.6	82.0	82.3	81.3	81.8	81.3	80.5	81.8
LS	Aces	2.8	3.2	3.6	3.1	3.3	3.2	3.6	3.7	2.8	3.3
	Double faults	6.0	4.7	5.3	4.7	5.7	4.4	5.1	4.9	4.7	5.0
	1st services in	59.0	62.6	61.9	60.5	60.1	61.6	62.6	63.7	61.4	61.5
	Games won on service	63.4	64.2	65.6	64.8	63.7	63.1	67.2	63.8	62.1	64.3

Table 6 - Service characteristics depending on the age of the balls.

The age of the balls is indicated from 1 (new balls) to 9 (old balls). During the five minutes of warming up before the match begins, the same balls are used as in the first 7 games. Thus it makes sense to set the age of the balls in the first game at 3. If the hypothesis were true, the probability of winning a service game would decrease with the age of the balls. If we look at the men's singles, we see that the estimated probability of winning a service game is 83.3% when serving with new balls (age=1) and 80.5% when serving with old balls (age=9). Although the difference is not significant, it seems to indicate that there might be an effect, at least in the men's singles. In the first game with new balls, the server produces more aces and more double faults, his first service is less frequently in than in other games, but if it is in, he scores more points on it, and on the whole he does better. The reason for this, in all probability, is that the new balls are harder and less fluffy (hence less grip) than the old balls. The service is therefore less easy to control, resulting in less first services in and more double faults. However, if the first service is in, then it is faster and produces more aces. In addition, the new balls make it more difficult for the receiver to hit a good return. So, even though less services are in with the new balls, the number of games won on service is higher. Table 6 shows also that the possible "new balls" effect is evident only in the first game with new balls. After the first game the players have become used to the balls again.

In the ladies' singles too, less first services are in and more double faults are produced in games with new balls, even significantly so. However, in contrast to the men's singles, less aces are produced and there is less service dominance than in the average game. Like in the men's singles, the new balls make the first service go faster and less easy to control. But unlike in the men's singles, the service is still not sufficiently fast to cause problems for the receiver.

We now turn to another aspect of the balls. A major discussion in tennis concerns the service dominance and the effect it has on the attraction of tennis. This, of course, is particularly true on fast grass courts such as Wimbledon. Many proposals have been made to reduce the dominance of the service: making the net higher or the service court smaller, abolishing the second service, using softer balls, to name just a few. The last proposal was put into effect at the 1995 Wimbledon Championships.

Hypothesis 5: In the 1995 Wimbledon Championships softer balls were used than in previous years. This has resulted in less service dominance.

Before we can address Hypothesis 5, we need to know something about the weather, since this also affects the balls. If the weather had been very different in 1995 than in the three previous years, then it would have been difficult to make proper comparisons. The Wimbledon weather is documented by Little (1995) who shows that the weather has not been very different in the four years of our observations. In Table 7 the four years are compared through some service characteristics.

	MS					LS				
Percentage of ...	1992	1993	1994	1995	Total	1992	1993	1994	1995	Total
Aces	8.7	8.6	9.1	10.0	9.1	3.2	3.5	3.0	3.4	3.3
Double faults	4.6	5.5	5.1	6.1	5.5	4.2	5.1	5.3	5.4	5.0
Points won if 1st service in	73.8	74.0	74.2	74.8	74.2	63.2	63.9	62.9	61.4	62.8
Points won if 2nd service in	59.3	60.7	58.9	59.5	59.6	52.4	52.6	52.0	54.8	53.1
Games won on service	82.1	82.1	81.9	81.1	81.8	65.0	64.9	64.3	63.0	64.3

Table 7 - Service characteristics depending on the year of tournament.

At first glance the softer balls seem to have had an effect. The probability of winning a service game in

1995 was 81.1% for the men's singles, somewhat lower than the average over the four years which is 81.8%. Similarly, in the ladies' singles the estimated probability was 63.0% in 1995 compared to a four year average of 64.3%. A more careful investigation shows, however, that this decrease in service dominance has little to do with the softer balls. Over the last four years the service dominance has gradually declined, both in the men's singles and in the ladies' singles.[11]

The prime reason why the service dominance has declined is, we believe, that the return of service of many professional players has much improved. As a result, the pressure on the server to take risks has gone up. This is especially noticeable in the men's singles, where the server produces more aces and more double faults than in previous years and where, if the first service is in, he scores more frequently. Since on the whole the number of service games won has decreased in the men's singles, it appears to be the case that both service and return of service have improved, but that the improvement of the return of service dominates.

So, the service dominance seems to decrease somewhat even without special measures. The use of softer balls seems to have had no effect, at least not the balls used in 1995. If decreasing the dominance of the service is deemed necessary, then stronger measures are called for. The most obvious and most easy to implement measure is to abolish the second service; see the discussion following Tables 3A and 3B.

[11] The relatively large decrease in the percentage of games won on service from 1994 to 1995 is not significant.

5 Big points

Few readers would disagree that a point played at 30-40 in a game is more important than, say, at 0-0. Similarly, a game at 4-4 in a set is more important than a game at 1-1. And the final set is more important than the first set. The question which concerns us in this section is whether players play each point "as it comes" or that they are affected by what happened in the previous point (ace, double fault) and/or by the importance of the point (break point, game point). After a double fault, are there less aces and more first services in? Do players make sure their first service is in at break point or game point? Do the "real champions" play their best tennis at the big points? These are the type of questions which we shall investigate in this section. If there are big points and if players don't play each point as it comes, then clearly the points are neither independent nor identically distributed, and this will have important consequences for the statistical modelling of tennis matches.

We begin with the question whether the points are independent. If they are, then the point following a double fault or an ace should not be any different from other points. A double fault in the men's singles occurs in 5.1% (0.1%) of the points when a seeded player serves and in 5.7% (0.1%) of the points when a non-seeded player serves (seeded and non-seeded receivers taken together). In the ladies' singles, 4.1% (0.2%) for a seeded server and 5.9% (0.2%) for a non-seeded server. Hence, seeded players serve significantly less double faults than non-seeded players. It would, of course, be naive to think that the better a player is, the less double faults he/she serves or that no double faults is a sign of good play. The players at Wimbledon apparently believe that the optimal balance between loosing a point because of a double fault and loosing a point because of too easy a second service is to choose that amount of risk which leads to about 5% double faults. One would think that the opponent plays a role as well in determining the number of double faults. After all, against a weaker opponent one does not have to take the same risks and this would lead to less double faults. Interestingly, this effect is negligible. A player serves about the same number of double faults, whether his/her opponent is seeded or non-seeded; see Tables 3A and 3B.

Let’s now consider whether a double fault affects the way a player serves in the next point. This is one aspect of the question whether a point is played independently from the previous point.

Hypothesis 6: After a double fault most players make sure their next first service is in.

One hears this often and it makes sense, because players wish to avoid two consecutive double faults. They would therefore take less risk by increasing the number of 1st services in and decreasing the number of aces. In the men's singles the percentage of 1st services in is 59.5% over all points and 59.7% after a double fault. This difference is negligibly small. In the ladies' singles, however, the percentage of 1st services in increases significantly from 61.5% (all points) to 65.7% (after double fault). On the basis of this result we would be tempted to conclude that women are affected by a double fault in the previous point, but that men are not.

	Percentage of ...	Sd-Sd	Sd-NSd	NSd-Sd	NSd-NSd	Total	All points
MS	Aces	10.9	9.7	7.6	6.4	8.2	9.1
	Double faults	6.9	5.0	5.1	5.8	5.4	5.5
	Points won on service	65.0	68.8	61.9	64.0	64.8	65.0
	1st services in	60.6	55.4	62.2	60.7	59.7	59.5
LS	Aces	2.7	2.2	2.3	2.7	2.4	3.3
	Double faults	2.7	5.2	5.8	6.4	5.4	5.0
	Points won on service	59.7	63.6	50.2	55.0	56.0	56.4
	1st services in	69.1	65.3	67.2	62.1	65.7	61.5

Table 8 - Service characteristics of the point after a double fault (same server).

However, the situation is not quite so simple. It is true that the women are affected by a double fault. If we compare Table 8 with Table 3B, then we see that in all four sub-categories the percentage of aces becomes smaller after a double fault (especially when a seeded player serves against a non-seeded player) and the percentage of 1st services in becomes larger (especially when a non-seeded player serves against a seeded player). In the men's singles too the percentage of aces decreases in the point following a double fault in all sub-categories, although only marginally and not significantly; see Tables 8 and 3A. Also the percentage of 1st services in increases in three sub-categories. However, if a seed serves against a non-seed, the percentage of 1st services in decreases significantly after a double fault (from 59.5% to 55.4%) rather than increases. This is a somewhat puzzling result, since it indicates an increase in risk taking after a double fault, whereas the decline in the percentage of aces indicates the opposite. Further data will be required to resolve this contradiction. We conclude that Hypothesis 6 appears to be true in the ladies' singles, but that we are not convinced about its truth in the men's singles.

Still on the subject of independence of points, let us now consider the point following an ace. In general, an ace in the men's singles occurs in 11.3% (0.2%) of the points when a seeded player serves and in 7.6% (0.1%) of the points when a non-seeded player serves. In the ladies' singles, 3.9% (0.2%) for a seeded and 2.7% (0.1%) for a non-seeded server. Hence, seeded players serve significantly more aces than non-seeded players. The strength of the opponent matters a bit, especially in the ladies' singles, but not much.

Unlike all other hypotheses in this paper, which are statements often heard from commentators and other "experts", the following is our own invention.

Hypothesis 7: An ace is worth more than one point.

Serving an ace obviously earns you one point. How can it earn you more than one point? It could, if, following an ace, the server has gained so much extra confidence that he/she does significantly better in the next point too. In other words, if serving an ace affects the next point.

	Percentage of ...	Sd-Sd	Sd-NSd	NSd-Sd	NSd-NSd	Total	All points
MS	Aces	14.7	15.5	11.1	10.5	13.1	9.1
	Double faults	4.5	5.2	5.9	5.1	5.3	5.5
	Points won on service	70.4	72.9	63.3	68.0	68.9	65.0
	1st services in	57.8	58.5	57.0	58.5	58.0	59.5
LS	Aces	4.6	7.7	3.5	5.1	5.7	3.3
	Double faults	5.5	4.7	6.1	9.5	6.1	5.0
	Points won on service	51.4	63.8	49.0	59.9	57.3	56.4
	1st services in	59.6	54.4	60.6	48.2	55.7	61.5

Table 9 - Service characteristics of the point after an ace (same server).

A comparison of Table 9 with Table 3 shows that, after an ace, a player will take more risk and with success: there will be more aces, less 1st services in and, on the whole, more points won on service. If Hypothesis 7 is true and an ace is worth more than one point, perhaps we can also say how much more it is worth. Indeed we can. In the men's singles an ace is worth 1.04 points and in the ladies' singles 1.01 points, a small increase but not unimportant, especially in the men's singles.[12]

We next address the question whether points are identically distributed. So we don't ask what happens in the point *following* another point (ace, double fault), but rather what happens *at* a particular point. For example, at game point or break point, is it particularly important to have your first service in?

Hypothesis 8: Good players make sure their first service is in at game point or break point.

We shall consider Hypothesis 8 together will another hypothesis, possibly the best known of all.

Hypothesis 9: The real champions play their best tennis at the big points.

In this paper we will only discuss one of many possible interpretations of this important hypothesis. If we think of all break points as big points (which is of course a drastic simplification), then Hypothesis 9 can be interpreted as follows: Seeded players perform better at break points, whereas non-seeded players do not.

Tables 10 and 11 will assist us in analysing Hypotheses 8 and 9.

[12] For example, we have from Table 9, 1.0 + 0.689 - 0.650 = 1.039 in the men's singles.

	Percentage of ...	Sd-Sd	Sd-NSd	NSd-Sd	NSd-NSd	Total	All points
MS	Aces	11.9	12.9	10.3	9.0	10.9	9.1
	Double faults	5.6	5.5	5.7	5.8	5.7	5.5
	Points won on service	65.0	69.7	62.5	63.7	65.4	65.0
	1st services in	56.9	57.1	58.4	57.2	57.5	59.5
LS	Aces	3.8	5.1	3.7	3.6	4.2	3.3
	Double faults	3.2	5.1	5.7	7.0	5.3	5.0
	Points won on service	56.0	63.9	50.0	58.4	57.5	56.4
	1st services in	66.4	58.5	60.7	59.9	60.6	61.5

Table 10 - Service characteristics at game point.

	Percentage of ...	Sd-Sd	Sd-NSd	NSd-Sd	NSd-NSd	Total	All points
MS	Aces	11.1	10.4	5.8	5.8	7.4	9.1
	Double faults	3.8	4.9	5.7	6.9	5.7	5.5
	Points won on service	65.6	69.5	58.0	60.9	62.2	65.0
	1st services in	61.8	61.0	60.8	57.8	60.1	59.5
LS	Aces	4.1	3.2	2.0	1.8	2.6	3.3
	Double faults	2.9	3.1	4.5	6.2	4.3	5.0
	Points won on service	58.3	58.2	49.0	54.0	53.5	56.4
	1st services in	68.5	64.0	60.8	60.9	62.7	61.5

Table 11 - Service characteristics at break point.

First of all, we define a game point as one of the scores 40-0, 40-15, 40-30 and advantage server, but not, say, 30-40, even though the score is one point away from game. Comparison of Table 10 with Table 3 shows that Hypothesis 8 is wrong as far as game points are concerned. If anything, the results point in the opposite direction. At game point the percentage of 1st services in is 57.5% in the men's singles (59.5% over all points which is significantly larger) and 60.6% in the ladies' singles (61.5% over all points which is insignificantly larger). We also observe more aces and slightly more points won on service. Moreover, this holds for the men's singles as well as for the ladies' singles. Hence, at game point, the server, being in a winning mood, takes more risks or the receiver tries less hard, or both.

At break point, however, the server is, on the whole, more risk averse (see Table 11) and achieves a slightly higher percentage of 1st services in. Hence, Hypothesis 8 appears to be false at game point, but true at break point.

Break points are more important than game points for both the server and the receiver. These are the points where the seeded player, on service break point down, would perform particularly well (Hypothesis 9), for example by hitting an ace. If the seeded player, while serving, performs relatively well under pressure (that is, at break point), this is not reflected in the number of aces. In the men's singles the percentage of aces served by the seeded player drops from 11.3% to 10.6% and in the ladies' singles from 3.9% to 3.5%. The drops are not significant, but they show that, if there is any difference at all, the seeded player serves less rather than more aces. The non-seeded player, when serving at break point, also serves less aces, but this difference is significant: the men produce only 5.8% (0.4%) aces at break point compared to 7.6% (0.1%) in general, while the women hit 2.0% (0.3%) aces at break point compared to 2.7% (0.1%) in general.

This reduction in the percentage of aces reflects that, at break point, players make sure their 1st service is in (Hypothesis 8) and hence take less risk. Both men and women also win significantly less points at break point down than otherwise: 62.2% < 65.0% (MS) and 53.5% < 56.4% (LS) (compare Tables 11 and 3). For the men, this difference can be solely attributed to the non-seeded servers. We are tempted to conclude that it is not true that, when serving at break point, the seeded players play their best tennis, but rather that the non-seeded players play their worst. However, a more plausible interpretation is that the seeded server, break point down, performs better and so does the receiver (seeded or non-seeded), and that these two improvements cancel. In contrast, a non-seeded server, break point down, does *not* perform better, while the receiver (seeded or non-seeded) does. So, Hypothesis 9 appears to be true for the men. However, not for the women, since in the ladies' singles, somewhat puzzlingly, the difference between 53.5% and 56.4% can be solely attributed to (relatively) good play of non-seeded receivers.

Hypotheses 8 and 9 are concerned with the question whether players behave differently at particular points in a game, in this case game point or break point. The next hypothesis is concerned with the question whether players behave differently at a particular game in a set.

Hypothesis 10: The 7th game is the most important game in the set.

We don't know the history of this "wisdom", but there is no doubt that many (and, in particular, many commentators) believe it. We can measure the importance of a game in two ways, weighted or unweighted. The unweighted importance of a game in a set, assuming that the game occurs in the set, is defined as the probability that the server in that game wins the set given that he/she wins the game minus the probability that the server wins the set given that he/she looses the game.[13] [14] The unweighted importance does not take into account that some games (like the 12th) occur much less frequently than other games (such as the first 6). The weighted importance takes this into account by defining weighted importance as unweighted importance times the probability that the game occurs.

[13] If we had defined the unweighted importance of a game in a set as the probability that the server in that game wins the set given that he/she wins the game, then we would not have taken account of the fact that, after the first set, in odd games usually the player who won the previous set (often the weaker player) serves. See the discussion at Hypothesis 2.

[14] The tie-break and games after 6-6 in the final set are not considered in Table 12.

		1	2	3	4	5	6	7	8	9	10	11	12	Mean
MS	Unweighted	33.9	32.6	33.0	41.6	34.7	43.0	38.4	34.7	43.2	59.1	49.7	56.9	44.1
	Weighted	33.9	32.6	33.0	41.6	34.7	43.0	37.6	31.2	33.6	32.7	14.2	16.2	39.3
LS	Unweighted	37.7	41.1	40.1	34.3	34.5	41.3	39.8	42.1	34.0	52.4	58.5	53.1	42.4
	Weighted	37.7	41.1	40.1	34.3	34.5	41.3	36.6	31.6	18.9	19.3	9.3	8.4	39.7

Table 12 - (Un)weighted importance of each game in a set.

As Table 12 shows, Hypothesis 10 is clearly nonsense. Unweighted, games 10 and 12 in the men's singles and games 10, 11 and 12 in the ladies' singles are the most important. There is no indication that the 7th game plays a special role. Since the 10th, 11th and 12th games don't occur as frequently as the first 6 games, their weighted importance is rather less. Weighted, the 7th game does not play a special role either. If anything, the 6th game is more important, both in the men's singles and in the ladies' singles, although this result is statistically insignificant. Hence we reject Hypothesis 10.

Up to now we have assumed that big points exist. But do they?

Hypothesis 11: All points are equally important.

The previous discussion makes it plausible that not all points are equally important and that the players (especially the non-seeded players) behave differently at break points. We have one further piece of evidence, which is presented in Table 13.

	MS		LS	
Set	P_{Sd}-P_{NSd}	Sd wins set	P_{Sd}-P_{NSd}	Sd wins set
1	9.3	79.7	11.5	77.6
2	8.9	78.5	14.4	84.2
3	7.3	69.6	11.0	83.3
4	7.3	70.7	-	-
5	4.3	70.4	-	-
Total	8.1	75.0	12.7	81.2

Table 13 - Two measurements of the strength of a seeded player relative to a non-seeded player. (P_{sd} (P_{NSd}) is the estimated probability of seeded (non-seeded) player winning a point on service versus a non-seeded (seeded) player.)

We can measure the strength of a seeded player relative to a non-seeded player by P_{Sd} - P_{NSd}, where P_{Sd} denotes the estimated probability that the seed wins a point while serving against a non-seed and P_{NSd} denotes the estimated probability that the non-seed wins a point while serving against a seed. The probabilities for all sets taken together are given in Tables 3A and 3B above. For the men, P_{Sd} = 69.3% and P_{NSd} = 61.2% and hence P_{Sd}-P_{NSd} = 8.1%, whereas for the women P_{Sd} = 62.9% and P_{NSd} = 50.2% and hence P_{Sd}-P_{NSd} = 12.7%. The difference between seeds and non-seeds is thus greater in the ladies' singles than in the men's singles, not surprisingly. There is a second way to measure the difference in strength, namely the estimated probability that the seed wins a set from the non-seed. This is 75.0% in the men's singles and 81.2% in the ladies' singles and we reach the same conclusion. In Table 13 we present these two measures by set.[15] We see that the difference in strength between a seeded and a non-seeded player (as measured by P_{Sd}-P_{NSd}) decreases gradually in the men's singles, but not in the ladies' singles. However, in both the men's singles and the ladies' singles, the difference in strength is least in the final set (4.3% in the MS, 11.0% in the LS). This is what we would expect. In the deciding final set we don't expect a lot of difference in strength any more, even though a seed and a non-seed play each other. Now a curious phenomenon occurs. Even though, in the final set, the number of points won by the seed is not very much larger than of the non-seed, the seed still has a very much larger chance to win the final set. And this is true both for the men and for the women. There is only one possible explanation, and that is that the seeds play the important points better (or equivalently, that the non-seeds play them worse). We conclude that not all points are equally important and that the non-seeds have particular problems playing them.

[15] Compare Tables 17A and 17B in Section 7.

6 Breaks

The server is expected to win his or her service game. If he or she fails to do so, this is considered serious in the ladies' singles and disastrous in the men's singles. A game won not by the server but by the receiver is called a "break". In the men's singles breaks occur 18.2% of the time, in the ladies' singles 35.7%; see Tables 3A and 3B. The better the players, the more serious it is to be broken. When two seeds play each other, breaks occur in 13.9% of the games in the men's singles, 33.4% in the ladies' singles. When two non-seeds play against each other, breaks occur more often: 19.6% in the men's singles and 35.7% in the ladies' singles.

Most people believe in the "break-rebreak" effect, which is our next hypothesis.

Hypothesis 12: After breaking your opponent's service there is an increased chance that you will loose your own service.

In the previous section we discussed the independence of *points* and we illustrated the suspected dependence by asking whether the point following a double fault or an ace is any different from other points. We decided that there are indications that it is. Hypothesis 12, however, relates to the independence of *games*.

	Previous game	Sd-Sd	Sd-NSd	NSd-Sd	NSd-NSd	Total
MS	Break	86.9	87.2	73.9	83.0	83.3
	Break point(s), but no break	87.7	91.8	71.0	75.3	80.7
	No break point	85.4	89.0	75.2	80.1	81.6
	All games	86.1	89.0	74.4	80.4	81.8
LS	Break	67.4	77.6	51.3	66.7	68.3
	Break point(s), but no break	61.3	75.2	49.3	49.4	60.4
	No break point	66.6	78.0	48.6	66.0	62.0
	All games	66.6	77.6	49.8	64.3	64.3

Table 14 - Estimated probabilities of winning a service game depending on what happened in the previous game (same set).

Referring to Table 14, Hypothesis 12 appears, at first sight, to be wrong. Overall, the probability of winning a service game increases rather than decreases after a break, in the men's singles from 81.8% to 83.3%, in the ladies' singles from 64.3% to 68.3%. The increase is 1.5%-points (1.0%) in the men's singles and 4.0%-points (1.4%) in the ladies' singles, hence somewhat marginal for the men, but highly significant for the women.

The reader may protest by arguing that we should only consider matches between players of equal strength, Sd-Sd or NSd-NSd, because with players of unequal strength (Sd-NSd and NSd-Sd) it is to be expected that the stronger player often breaks the weaker player and then goes on to win his/her own service game, whether Hypothesis 12 is true or not. This event could dominate in the aggregate figures described above, so that these are no true indications of the opposite of Hypothesis 12. However, even if we constrain ourselves to matches between players of equal strength, then Hypothesis 12 is still incorrect, as Table 14 shows. Hence, our conclusion is unchanged: after a break, the players are more, rather than less, likely to win their service game. Thus, although Hypothesis 12 is based on the belief that, in the game following a break, the winner takes it a bit easier and the looser tries a bit harder, apparently, what happens is just the opposite. The winner gains in confidence and the looser gets slightly discouraged.

Next, we suppose that in the previous game no break has occurred, but that the receiver had a good chance to break because he/she had one or more break points. The receiver did not capitalise on these break points and this may have discouraged him/her.

Hypothesis 13: After missing break points in the previous game there is an increased chance that you will loose your own service.

Table 14 shows that this hypothesis has some support. The probability of a break is higher than usual (1.1%-points higher in the men's singles, 3.9%-points higher in the ladies' singles), but not significantly so. The "discouragement effect" is particularly strong when two non-seeds play against each other. There the probability of loosing a service game after missed break points in the previous game increases by 5.1%-points (2.8%) in the men's singles and a spectacular 14.9%-points (5.9%) in the ladies' singles. This adds support to the idea that seeded players are not only technically but also mentally stronger than non-seeded players. They don't let themselves be discouraged and are less affected by what happened in the previous point or game.

Where Hypotheses 12 and 13 concern two consecutive games in the same set, the next hypothesis concerns the final game (possibly a tie-break) in one set and the first game in the next set.

Hypothesis 14: After winning a set there is an increased chance that you will loose the first game in the next set.

The idea is the same as in Hypothesis 12. The winner of the set is happy to relax while the looser is anxious to make an early break in the new set. But again, maybe the opposite is the case: the winner has gained confidence and performs even better than before?

		Sd-Sd	Sd-NSd	NSd-Sd	NSd-NSd	Total
MS	First game after current server won set	85.7	88.3	75.6	86.1	85.2
	lost set	84.2	87.8	71.4	77.4	77.6
	Other games after current server won set	85.6	89.6	77.2	85.0	85.7
	lost set	83.4	85.6	73.6	73.4	76.8
LS	First game after current server won set	68.7	76.7	63.2	66.7	71.4
	lost set	68.2	67.9	49.4	46.7	54.7
	Other games after current server won set	69.4	81.0	50.0	69.8	71.8
	lost set	59.6	71.1	46.9	57.1	55.0

Table 15 - Estimated probabilities of server winning first game and other games in a set depending on who won the previous set.

Some care is required interpreting Table 15. Comparing rows 1 and 2, we see that the probabilities in row 2 are always lower than in row 1 (and similarly, rows 3 and 4, 5 and 6, 7 and 8). This shows that a player in the men's singles who serves in the first game of the new set is more likely to be successful if he won the previous set than if he lost it. This is not surprising, because if he won the previous set he is probably the better player. What we should compare is rows 1 and 3, 2 and 4 for the men's singles and 5 and 7, 6 and 8 for the ladies' singles. This will show whether the outcome of the previous set has an effect on the first game which differs from its effect on the other games of the set. In other words, it will show whether the winner of the previous set will "take it easy" in the first game or, on the contrary, is "ready for the kill".

Table 15 shows that neither is the case. The first game of a new set (with the exception of the first game in the first set, see the "first game effect" discussed under Hypothesis 3) is nothing special. There are, however, two remarkable exceptions, both in the ladies' singles. The first is that a non-seeded player, having won a set from a seeded player, appears to serve particularly well in the first game of the new set (63.2% > 50.0%). The second exception is that a non-seeded player, having lost a set against another non-seeded player, has a particularly small chance of winning her service in the first game of the new set (46.7% < 57.1%). These two exceptions are in harmony with the previous discussion. Our findings strongly suggest a positive correlation between points (and games), that is, a “winning mood effect”: if you do well in one point (game) you will also do well in the next point (game). This effect appears to dominate the often heard negative correlation idea: if you do well (break service, win a set, etcetera), don't loose your concentration, because your opponent is going to hit back. Furthermore, the positive correlation is stronger with non-seeded than with seeded players. Hence: *The stronger a player is, the less is he/she affected by what happened in the previous points.*

Our final hypothesis in this section is

Hypothesis 15: One break is enough to win the set.

From one point of view this hypothesis is trivially true. Given that there is one break in a set, the player who has broken does not need a second break. One break is enough. What we mean, however, is: If you achieve the first break in a set, how confident can you be that you will win the set? After all, you may be broken back.

For each set score (6-0, 6-1, etcetera), we have tabulated the relative frequency of the total number of breaks. For example, 6-0 can only occur with 3 breaks. But 6-1 can occur with 2, 3, 4 or 5 breaks. This leads to Tables 16A (men's singles) and 16B (ladies' singles).

Score	0	1	2	3	4	5	6	7	Total
6-6	11.5	-	6.0	-	1.8	-	0.3	-	19.6
7-5	-	4.2	-	3.7	-	1.1	-	0.1	9.1
6-4	-	17.9	-	7.4	-	1.5	-	0.0	26.7
6-3	-	13.1	4.7	3.6	0.9	0.1	0.1	0.0	22.5
6-2	-	-	11.3	-	1.2	-	0.0	-	12.4
6-1	-	-	6.1	1.8	0.2	0.0	-	-	8.1
6-0	-	-	-	1.6	-	-	-	-	1.6
Total	11.5	35.2	28.1	18.0	4.1	2.6	0.4	0.1	100.0

Table 16A - Relative frequency distribution of the total number of breaks in a set for different set scores: men’s singles.

Score	0	1	2	3	4	5	6	7	8	9	10	Total
6-6	0.4	-	3.2	-	2.4	-	1.2	-	0.4	-	0.2	7.8
7-5	-	1.0	-	2.4	-	4.0	-	0.8	-	0.0	-	8.2
6-4	-	5.2	-	7.4	-	7.4	-	0.8	-	0.0	-	20.7
6-3	-	4.4	2.4	5.4	4.4	0.8	1.6	0.2	0.0	-	-	19.1
6-2	-	-	10.1	-	7.6	-	1.2	-	-	-	-	18.9
6-1	-	-	8.2	6.4	2.2	0.4	-	-	-	-	-	17.1
6-0	-	-	-	8.3	-	-	-	-	-	-	-	8.3
Total	0.4	10.5	23.9	29.8	16.5	12.5	4.0	1.8	0.4	0.0	0.2	100.0

Table 16B - Relative frequency distribution of the total number of breaks in a set for different set scores: ladies’ singles.

In the tables, cells with a dash (-) indicate score/break combinations which can not occur. For example, the score 6-0 can not occur with 0 breaks (only with 3 breaks). The score 6-6 contains all the sets where a tie-break occurred and also the 5th (3rd) sets with scores 8-6, 9-7, etcetera. For the score 6-6 we count the number of breaks during the first 12 games only. In theory, a set could contain 12 breaks (even more in the final set), but in our data set the maximum number of breaks is 7 in the men's singles and 10 in the ladies' singles.[16]

Of the 950 sets observed in the men's singles there are 109 (11.5%) where each game goes with service until the score 6-6 has been reached. In the ladies' singles it is extremely rare to reach 6-6 without breaks. Of the 503 sets in our data set there are only 2 (0.4%) where this happens. A score of 6-0 is very rare in the men's singles (1.6%), but not so rare in the ladies' singles (8.3%). The most common set score is 6-4 both for the men (26.7%) and the women (20.7%). In the men's singles, 1 break is the most likely; in the ladies' singles, 3 breaks is the most likely.

If there are no breaks (which occurs only at the score 6-6), then we take this as evidence that one break would have been enough. If there is 1 break, then clearly 1 break was enough. If there are 2 or 3 breaks, all by the same player, then we assume that 1 break would have been enough. In all other cases 1 break was not enough. For example, at the score 6-4 with 3 breaks (2 for the winner of the set, 1 for the looser), the second break for the winner was necessary to win the set (without a tie-break), so that 1 break was not enough. Adding up the nine relevant percentages gives 72.2% in the men's singles and 46.4% in the ladies' singles. Hence, in the men's singles, it is true that usually 1 break is (or would have been) enough. In only 27.8% of the sets 2 or more breaks are required. In the ladies' singles, however, 1 break is usually not enough.

There is another way to consider Hypothesis 15, namely by estimating the probability that the player who breaks first also wins the set. When two players of equal strength (both seeded or both non-seeded) play against each other, the estimated probability of winning the set after one break increases from 50.0% to 85.4% in the men's singles and to 74.1% in the ladies' singles. Hence, a break is more important for the men than for the women, but for the women it also provides a substantial increase in the chance of winning the set. When a seeded and a non-seeded player play against each other, the probability that the seeded player wins a set is 76.1% (MS) and 81.2% (LS): the gap between seeded and non-seeded players is larger in the ladies' tournament than in the men's.[17] If the seeded player breaks the service of the non-seeded player his/her probability of winning the set increases from 76.1% to 93.2% (MS) and from 81.2% to 94.9% (LS). Conversely, if the non-seeded player breaks the service of the seeded player his/her probability of winning the set increases from 23.9% to 66.9% (MS) and from 18.8% to 59.3% (LS).

We now have two interpretations of Hypothesis 15. In the first interpretation we conclude that one break

[16] Maleeva-Fragniere beat Godridge 7-5, 7-6 in the third round, 1992. Of the 12 games played in the second set until the tie-break, only 2 went with service.

[17] The probability that a seeded player wins a match against a non-seeded player is 86.7% (MS) and 88.8% (LS), respectively. The difference of 2.1%-points is smaller than the difference at set level (5.1%-points), because the women play a maximum of 3 sets, while the men play a maximum of 5 sets.

is enough in the men's singles, but not in the ladies' singles. In the second interpretation we conclude that one break is usually enough, both in the men's singles and the ladies' singles, but that it depends on who plays whom. If a seeded player breaks a non-seeded player, he/she is almost certain to win the set. With two players of equal strength, the player who breaks will win the set four out of five times, approximately. And if a non-seeded player breaks a seeded player, his/her probability of winning the set increases to significantly more than one half, but there is still a substantial chance that the seed will break back and win the set.

How can the two, apparently contradictory, results for the ladies' singles be reconciled? The answer is that, even though in the ladies' singles one break is usually not enough (three is the most common number of breaks), nevertheless the player who forces the first break will have a big advantage. Further breaks will usually occur in the set (unlike in the men's singles), but the woman who breaks first is strong favourite to win the set. So, Hypothesis 15 is true for the men and both true and not true for the women. Most sets in the ladies' singles require more than one break, but the first break gives a clear advantage in winning the set.

7 The final set

The final set (5th in the men's singles, 3rd in the ladies' singles) decides the match. Tension is high and mistakes can be very costly. In the men's singles 19.8% of the matches went to 5 sets, in the ladies' singles 25.6% went to 3 sets in our data set. There are a number of interesting questions relating to the final set. For example, suppose a seed plays against a non-seed. You wish to forecast the winner. At the beginning of the match, if no further information is available, the probability that the non-seed wins is small: 13.3% (MS) and 11.2% (LS). What is the probability at the beginning of the final set? Is it now close to 50%? The answer is that it is not. Naturally, the probabilities have increased, but only to 29.6% (MS) and 16.7% (LS); see Table 13. At 2-2 in sets in the men's singles, it is therefore certainly not true that the chances are now even between the seed and the non-seed. The seed is still very much the favourite. This is even clearer in the ladies' singles. At 1-1 in sets, the seeded player still has a probability of 83.3% to win the match!

Tennis matches can last for two or three hours or longer. The players get tired and therefore, possibly, their service becomes less powerful.

Hypothesis 16: In long matches the dominance of the service decreases.

Set	Sd-Sd	Sd-NSd	NSd-Sd	NSd-NSd	Total
1	68.6	70.3	61.0	64.5	65.5
2	67.4	69.4	60.5	63.9	64.9
3	65.8	68.7	61.4	63.7	64.6
4	68.5	68.9	61.6	64.1	65.3
5	62.1	67.9	63.6	63.3	64.5
Total	67.1	69.3	61.2	64.0	65.0

Table 17A - Estimated probabilities of winning a point on service: men’s singles.

Set	Sd-Sd	Sd-NSd	NSd-Sd	NSd-NSd	Total
1	57.8	62.6	51.1	56.6	56.8
2	56.9	63.4	49.0	55.7	56.0
3	53.8	62.1	51.1	57.0	56.0
Total	56.9	62.9	50.2	56.3	56.4

Table 17B - Estimated probabilities of winning a point on service: ladies’ singles.

Tables 17A and 17B present the probabilities of winning a point on service, by set and sub-category. We notice first that in the first 3 sets in the men's singles (first 2 sets in the ladies' singles) the service dominance decreases slightly, but consistently. The reason cannot be that the server gets tired, so it must be that the receiver gets increasingly better acquainted with his/her opponent's service and thus scores more points. Also, the number of aces decreases in the first 3 sets (9.7%, 9.1%, 9.0%) in the men's singles and the first 2 sets (3.4%, 3.0%) in the ladies' singles.

Regarding Hypothesis 16, there is no support for the idea that the service becomes less dominant in the final set, with the possible exception of matches between two seeds. But even there the more likely explanation is not that the server gets tired, but that the receiver puts more energy and concentration in each point. Hence, the receiver gets better rather than the server gets worse.

We complete our discussion with another well-known *idée reçue*.

Hypothesis 17: In the final set the player who has won the previous set has the advantage.

Let us consider Table 18 which, in contrast to previous tables, gives frequencies rather than relative frequencies.

	Sd-Sd		Sd-NSd				NSd-NSd		Total	
			Sd wins 4th (2nd) set		Nsd wins 4th (2nd) set					
	B	$\overline{B}$	B	$\overline{B}$	B	$\overline{B}$	B	$\overline{B}$	B	$\overline{B}$
MS	1	8	8	2	6	11	9	6	24	27
LS	3	6	18	5	1	12	10	2	32	25

Table 18 - Frequency distribution of winning both 4th and 5th set in men’s singles (2nd and 3rd set in ladies’ singles). (B: same player wins both sets; $\overline{B}$: not same player wins both sets.)

The number of observations is quite small: 51 final sets in the men's singles, 57 in the ladies' singles. In the men's singles the probability that the same player wins the fourth and fifth sets is estimated to be 47.1%. In the ladies' singles the estimated probability that the same player wins the second and third sets is 56.1%. Given the small amount of observations, these percentages are not significantly different from 50% and hence there is no ground for believing Hypothesis 17.

However, if we look at the sub-categories, then a pattern can nevertheless be abstracted from the data. In the men's singles, the probability that the same player wins the fourth and fifth sets is estimated to be

11.1% when two seeds play each other, 60.0% when two non-seeds play each other, and 51.9% when a seed and a non-seed play each other. In the ladies' singles the estimated probability that the same player wins the second and third sets is 33.3% when two seeds play each other, 83.3% when two non-seeds play each other, and 52.8% when a seed plays against a non-seed. Even though the number of observations is small, there appears to be some pattern. When two seeds play each other the winner of the 4th (2nd) set will probably loose the match, especially in the men's singles. When two non-seeds play each other, then the winner of the 4th (2nd) set will probably win the match, especially in the ladies' singles. And when a seed plays against a non-seed, it is irrelevant who won the 4th (2nd) set: the seeded player in the men's singles has an estimated probability of 70.4% (19/27) to win the match, in the ladies' singles of 83.3% (30/36), independent of what happened in the 4th (2nd) set; see also Table 13. Hence, there is some support for Hypothesis 17, but only in matches between two non-seeded players.

This hypothesis concludes our attack upon the *idées reçues* of tennis. We have attempted to investigate a number of commonly heard hypotheses, basing our analysis on point-by-point data of almost 500 singles matches played at Wimbledon during a period of four years (1992-1995). Many of the hypotheses turn out to be false or only partially true and we hope that this will be of interest to players, coaches, spectators and commentators of tennis.

References

Alefeld, B. (1984). "Statistische Grundlagen des Tennisspiels," *Leistungssport*, 3/84, 43-46.

Little, A. (1995). *Wimbledon Compendium 1995*, The All England Lawn Tennis and Croquet Club, Wimbledon, London.

Magnus, J.R. and F.J.G.M. Klaassen (1996). "Wat Tenniscommentatoren Niet Weten - Een analyse van vier jaar Wimbledon," *Kwantitatieve Methoden*, forthcoming.

Riddle, L.H. (1988). "Probability Models for Tennis Scoring Systems," *Applied Statistics*, 37, 63-75.