Poker Cards Analysis - April 2023

The Directors
Entain Plc

This is to confirm that iTech Labs has examined the game logs for Poker games for the period **Apr 01, 2023** to **Apr 30, 2023** as recorded by the respective game servers and analyzed the Poker cards for statistical randomness. The results of the analysis are given below.

For details on the gaming sites serviced by the Entain Plc game servers and used in this audit refer to the List.

1. Poker hand types statistics

These calculations were done for Royal Flush, Straight Flush, Four of a Kind, Full House, Flush, Straight, 3 of a Kind, 2 pairs, 1 Pair, High Card.

The Poker hand types analysis involved creating subsets of data and conducting Chi-square tests on each subset.

The null hypothesis for the chi-square test is that the observed frequencies of each type of hand matches the theoretical values for a deck that has been shuffled using a perfect random number generator. The p-values observed in these multiple tests are expected to follow a uniform distribution for the range 0.0 to 1.0.

The analysis performs a KS Test (Kolmogorov-Smirnov test) for uniform distribution on the observed p-values, and the combined p-value result of this test is taken as the final result of the Poker hand types statistics tests.

1.1 Poker hand types statistics for 52 cards deck:

Test No.	DOF	ChiSqr	P-Value
1	9	13.15	0.15588
2	9	3.36	0.94816
3	9	3.53	0.93933
4	9	11.92	0.21772
5	9	2.00	0.99140
6	9	9.47	0.39539
7	9	11.98	0.21439
8	9	9.16	0.42253
9	9	14.69	0.09993
10	9	14.16	0.11680
11	9	4.32	0.88889
12	9	9.27	0.41314
13	9	11.26	0.25814
14	9	10.31	0.32564
15	9	15.40	0.08053
16	9	15.28	0.08351
17	9	7.56	0.57875
18	9	10.15	0.33876
19	9	7.21	0.61496
20	9	8.49	0.48539
21	9	9.13	0.42511
22	9	7.50	0.58535
23	9	12.00	0.21352
24	9	6.54	0.68500
25	9	7.06	0.63087

26	9	8.28	0.50647
27	9	20.59	0.01461
28	9	9.82	0.36557
29	9	14.44	0.10762
30	9	6.50	0.68859
31	9	10.21	0.33385
32	9	4.39	0.88404
33	9	11.69	0.23120
34	9	6.88	0.65002
35	9	14.39	0.10921
36	9	7.97	0.53748
37	9	9.19	0.42015
38	9	7.57	0.57835
39	9	10.37	0.32150
40	9	12.94	0.16547
41	9	8.46	0.48820
42	9	15.20	0.08554
43	9	8.51	0.48369
44	9	3.85	0.92124
45	9	6.57	0.68195
46	9	9.22	0.41729
47	9	13.05	0.16028
48	9	7.54	0.58098
49	9	15.58	0.07614
50	9	7.97	0.53715
51	9	10.15	0.33840
52	9	10.38	0.32054
53	9	8.84	0.45239
54	9	12.35	0.19421
55	9	11.07	0.27098
56	9	4.93	0.84016
57	9	10.58	0.30544
58	9	5.73	0.76646
59	9	10.15	0.33854
60	9	9.83	0.36452
61	9	3.02	0.96359
62	9	10.01	0.34990
63	9	16.23	0.06229
64	9	7.35	0.60076
65	9	9.64	0.38033
66	9	4.69	0.86028
67	9	9.45	0.39714
68	9	6.25	0.71503
69	9	11.46	0.24536
70	9	7.54	0.58085
71	9	6.76	0.66193
72	9	8.25	0.50873
73	9	7.24	0.61249
74	9	3.62	0.93487
75	9	3.65	0.93313
76	9	4.65	0.86408
77	9	19.64	0.02029
78	9	4.06	0.90724
79	9	10.10	0.34232
80	9	4.92	0.84085
81	9	21.60	0.01025

82	9	5.01	0.83336
83	9	4.32	0.88902
84	9	5.95	0.74526
85	9	6.10	0.72983
86	9	2.29	0.98604
87	9	7.75	0.55991
88	9	4.87	0.84529
89	9	13.80	0.12971
90	9	8.07	0.52693
91	9	5.92	0.74801
92	9	5.40	0.79785
93	9	8.58	0.47714
94	9	10.89	0.28306
95	9	3.71	0.92925
96	9	4.69	0.86018
97	9	2.59	0.97847
98	9	14.75	0.09789
99	9	12.34	0.19470
100	9	4.43	0.88063
Combined P-value for all tests (Using KS method)			0.93193

Notes:

1) The P-values are observed probabilities from the Chi-Square tests. The last row shows the result of the KS Test performed on the p-values for all Chi-Square tests, where there are sufficient data.

1.2 Poker hand types statistics for 36 cards deck:

Test No.	DOF	ChiSqr	P-Value
1	8	5.05	0.75220
2	8	5.50	0.70330
Combined P-value for all tests (Using KS method)			N/A (Insufficient data)

Notes:

1) Since the number of samples available was insufficient to ensure at least 5 samples in the lowest probability hand type, (Royal Flush), the chi-square test has been performed by merging the Royal Flush and Straight Flush categories.
2) As the total number of tests (2) is insufficient to perform a meaningful KS Test, individual p-values from these tests are carried over to the next stage for combining using the Holm's method.
3) Since the number of games played each month using 36 card decks is small, the number of samples available this month as well as a few previous months were insufficient to perform a meaningful statistical analysis. Hence the analysis performed this month was done using the cumulative data for the last 4 months - i.e Jan 2023 to Apr 2023.

2. Poker rank statistics

The Poker rank analysis aims to establish that the rank of the cards in each position was equally distributed in one of the 13 possible ranks (2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K, A) for a 52 card deck and 9 ranks (6, 7, 8, 9, 10, J, Q, K, A) for a 36 card deck.

The Poker rank analysis involved creating subsets of data and conducting Chi-square tests on each subset. The analysis performs a KS Test (Kolmogorov-Smirnov test) for uniform distribution on the observed p-values, and the combined p-value result of this test is taken as the final result of the Ranks statistics tests.

2.1 Poker rank statistics for 52 cards deck:

Test No.	Positions	DOF	ChiSqr	P-Value
1	7	84	78.46	0.65003

2	7	84	71.43	0.83427
3	7	84	82.04	0.54016
4	7	84	81.49	0.55727
5	7	84	81.37	0.56106
6	7	84	86.79	0.39594
7	7	84	88.19	0.35607
8	7	84	73.78	0.77973
9	7	84	54.84	0.99424
10	7	84	71.28	0.83742
11	7	84	83.42	0.49742
12	7	84	81.22	0.56578
13	7	84	69.39	0.87449
14	7	84	72.55	0.80923
15	7	84	70.27	0.85795
16	7	84	79.81	0.60913
17	7	84	88.67	0.34273
18	7	84	100.09	0.11117
19	7	84	76.34	0.71167
20	7	84	89.63	0.31695
21	7	84	85.53	0.43316
22	7	84	80.73	0.58096
23	7	84	78.87	0.63765
24	7	84	98.72	0.13007
25	7	84	74.69	0.75650
26	7	84	79.95	0.60492
27	7	84	81.87	0.54534
28	7	84	90.57	0.29266
29	7	84	83.00	0.51021
30	7	84	100.42	0.10686
31	7	84	82.56	0.52397
32	7	84	72.92	0.80066
33	7	84	97.93	0.14208
34	7	84	97.90	0.14246
35	7	84	98.88	0.12778
36	7	84	110.55	0.02773
37	7	84	70.55	0.85238
38	7	84	92.76	0.24054
39	7	84	97.21	0.15368
40	7	84	74.00	0.77402
41	7	84	78.53	0.64802
42	7	84	82.65	0.52129
43	7	84	72.53	0.80958
44	7	84	87.78	0.36742
45	7	84	93.75	0.21881
46	7	84	75.43	0.73663
47	7	84	86.22	0.41257
48	7	84	93.88	0.21608
49	7	84	79.05	0.63241
50	7	84	79.30	0.62483
51	7	84	83.29	0.50129
52	7	84	88.47	0.34808
53	7	84	84.17	0.47423
54	7	84	78.83	0.63891
55	7	84	61.46	0.96939
56	7	84	82.60	0.52291
57	7	84	78.06	0.66191

58	7	84	82.79	0.51682
59	7	84	77.23	0.68627
60	7	84	84.09	0.47682
61	7	84	76.20	0.71566
62	7	84	87.47	0.37616
63	7	84	121.27	0.00487
64	7	84	84.13	0.47558
65	7	84	106.75	0.04762
66	7	84	112.38	0.02103
67	7	84	97.03	0.15664
68	7	84	66.31	0.92243
69	7	84	91.94	0.25931
70	7	84	93.13	0.23229
71	7	84	108.65	0.03654
72	7	84	86.82	0.39485
73	7	84	70.89	0.84542
74	7	84	67.95	0.89891
75	7	84	114.48	0.01517
76	7	84	86.63	0.40054
77	7	84	84.45	0.46572
78	7	84	95.50	0.18392
79	7	84	86.55	0.40281
80	7	84	51.99	0.99765
81	7	84	76.32	0.71218
82	7	84	72.22	0.81683
83	7	84	96.57	0.16447
84	7	84	84.21	0.47304
85	7	84	86.81	0.39528
86	7	84	72.15	0.81842
87	7	84	82.70	0.51955
88	7	84	109.61	0.03180
89	7	84	85.98	0.41957
90	7	84	80.22	0.59643
91	7	84	85.72	0.42736
92	7	84	95.69	0.18040
93	7	84	101.29	0.09637
94	7	84	111.12	0.02546
95	7	84	82.98	0.51088
96	7	84	62.04	0.96539
97	7	84	119.62	0.00649
98	7	84	81.30	0.56330
99	7	84	91.57	0.26814
100	7	84	69.83	0.86645
Combined P-value for all tests (Using KS method)				0.69645

Notes:

1) The P-values are observed probabilities from the Chi-Square tests. The last row shows the result of the KS Test performed on the p-values for all Chi-Square tests, where there are sufficient data.

2.2 Poker rank statistics for 36 cards deck:

Test No.	Positions	DOF	ChiSqr	P-Value
1	7	56	53.62	0.56533
2	7	56	47.14	0.79434
3	7	56	45.34	0.84491
4	7	56	54.33	0.53847
5	7	56	57.24	0.42880
6	7	56	61.71	0.27948
7	7	56	59.65	0.34430
8	7	56	61.60	0.28270
9	7	56	67.63	0.13724
10	7	56	63.95	0.21759
Combined P-value for all tests (Using KS method)				0.98569

Notes:

1) Since the number of games played each month using 36 card decks is small, the number of samples available this month as well as a few previous months were insufficient to perform a meaningful statistical analysis. Hence the analysis performed this month was done using the cumulative data for the last 4 months - i.e Jan 2023 to Apr 2023.

3. Poker suits statistics

The Poker suits analysis aims to verify that that the cards dealt exhibit an equal probability of all 4 suits (Clubs, Diamonds, Hearts and Spades) in all positions.

The Poker suits analysis involved creating subsets of data and conducting Chi-square tests on each subset. The analysis performs a KS Test (Kolmogorov-Smirnov test) for uniform distribution on the observed p-values, and the combined p-value result of this test is taken as the final result of the Suits statistics tests.

3.1 Poker suits statistics for 52 cards deck:

Test No.	Positions	DOF	ChiSqr	P-Value
1	7	21	23.86	0.30009
2	7	21	22.54	0.36888
3	7	21	21.07	0.45487
4	7	21	40.38	0.00668
5	7	21	11.86	0.94324
6	7	21	7.65	0.99646
7	7	21	16.44	0.74450
8	7	21	27.19	0.16460
9	7	21	17.75	0.66470
10	7	21	14.81	0.83252
11	7	21	26.46	0.18957
12	7	21	17.29	0.69337
13	7	21	31.52	0.06548
14	7	21	13.24	0.90006
15	7	21	18.84	0.59509
16	7	21	21.09	0.45321
17	7	21	32.76	0.04895
18	7	21	9.56	0.98409
19	7	21	17.35	0.68988
20	7	21	19.58	0.54812
21	7	21	18.33	0.62788
22	7	21	24.88	0.25259
23	7	21	19.05	0.58183
24	7	21	24.40	0.27404

25	7	21	23.86	0.30004
26	7	21	16.98	0.71216
27	7	21	38.77	0.01045
28	7	21	21.79	0.41149
29	7	21	24.50	0.26945
30	7	21	14.12	0.86458
31	7	21	18.46	0.61954
32	7	21	8.98	0.98939
33	7	21	21.04	0.45637
34	7	21	16.20	0.75842
35	7	21	15.77	0.78235
36	7	21	28.03	0.13941
37	7	21	22.48	0.37232
38	7	21	25.73	0.21681
39	7	21	17.02	0.70965
40	7	21	27.35	0.15970
41	7	21	18.35	0.62651
42	7	21	26.94	0.17271
43	7	21	12.94	0.91085
44	7	21	14.09	0.86571
45	7	21	20.65	0.48019
46	7	21	24.22	0.28268
47	7	21	21.91	0.40449
48	7	21	14.22	0.85992
49	7	21	20.08	0.51611
50	7	21	19.58	0.54783
51	7	21	14.18	0.86164
52	7	21	32.60	0.05079
53	7	21	22.45	0.37412
54	7	21	26.12	0.20179
55	7	21	19.45	0.55604
56	7	21	20.61	0.48316
57	7	21	17.66	0.67039
58	7	21	34.12	0.03515
59	7	21	30.38	0.08457
60	7	21	20.04	0.51851
61	7	21	13.60	0.88619
62	7	21	24.30	0.27897
63	7	21	24.37	0.27562
64	7	21	18.45	0.62039
65	7	21	27.86	0.14425
66	7	21	19.95	0.52435
67	7	21	28.45	0.12787
68	7	21	27.49	0.15517
69	7	21	23.49	0.31836
70	7	21	21.09	0.45330
71	7	21	15.92	0.77417
72	7	21	10.64	0.96940
73	7	21	15.44	0.80007
74	7	21	23.93	0.29624
75	7	21	14.15	0.86293
76	7	21	24.40	0.27426
77	7	21	16.08	0.76539
78	7	21	23.46	0.32001
79	7	21	28.96	0.11506
80	7	21	14.36	0.85362

81	7	21	40.19	0.00705
82	7	21	20.70	0.47726
83	7	21	17.30	0.69276
84	7	21	22.19	0.38853
85	7	21	28.45	0.12796
86	7	21	16.32	0.75160
87	7	21	17.06	0.70768
88	7	21	17.88	0.65676
89	7	21	15.73	0.78454
90	7	21	24.46	0.27126
91	7	21	27.97	0.14097
92	7	21	15.49	0.79749
93	7	21	10.51	0.97150
94	7	21	17.35	0.68991
95	7	21	21.46	0.43104
96	7	21	22.04	0.39701
97	7	21	25.90	0.21018
98	7	21	20.03	0.51922
99	7	21	19.76	0.53662
100	7	21	19.63	0.54476
Combined P-value for all tests (Using KS method)				0.99723

Notes:

1) The P-values are observed probabilities from the Chi-Square tests. The last row shows the result of the KS Test performed on the p-values for all Chi-Square tests, where there are sufficient data.

3.2 Poker suits statistics for 36 cards deck:

Test No.	Positions	DOF	ChiSqr	P-Value
1	7	21	30.33	0.08559
2	7	21	15.95	0.77234
3	7	21	27.38	0.15875
4	7	21	38.06	0.01270
5	7	21	21.37	0.43668
6	7	21	20.18	0.50963
7	7	21	25.22	0.23759
8	7	21	20.02	0.52025
9	7	21	9.63	0.98331
10	7	21	22.69	0.36063
Combined P-value for all tests (Using KS method)				0.86921

Notes:

1) Since the number of games played each month using 36 card decks is small, the number of samples available this month as well as a few previous months were insufficient to perform a meaningful statistical analysis. Hence the analysis performed this month was done using the cumulative data for the last 4 months - i.e Jan 2023 to Apr 2023.

4. Summary of the analysis

4.1 Summary of the analysis of 52 cards deck:

The analysis of 52 cards completes by combining the result of the KS Test performed in the 3 types of analysis (Hand Types, Ranks and Suits) for 52 card decks using the Holm's method and producing a single Combined P-value.

The combined p-value produced using the Holm's method is used as indication for statistical randomness.

Combination of p-values using Holm's Method		
Test	P-Value	P-Adjusted
Ranks Test	0.69645	1.00000
Suits Test	0.99723	1.00000
Hand Types Test	0.93193	1.00000
Combined P-Value using Holm's Method		1.00000

Notes:

1) The combined p-value of all statistical tests using Holm's Method conducted for 52 card decks is greater than the minimum value of 0.05 which indicates that the randomness of the observed data falls within 95% confidence limits.

The final outcome of the analysis of 52 cards deck indicates that the RNG is working correctly.

4.2 Summary of the analysis of 36 cards deck:

The analysis of 36 cards completes by combining the result of the KS Test performed in the 3 types of analysis (Hand Types, Ranks and Suits) for 36 card decks using the Holm's method and producing a single Combined P-value. Where there are insufficient data the individual Chi-Square tests results are used in the Holm's method for producing a combined p-value.

The combined p-value produced from the using the Holm's method is used as indication for statistical randomness.

Combination of p-values using Holm's Method		
Test	P-Value	P-Adjusted
Ranks Test	0.98569	1.00000
Suits Test	0.86921	1.00000
Hand Types Test 1	0.75220	1.00000
Hand Types Test 2	0.70330	1.00000
Combined P-Value using Holm's Method		1.00000

Notes:

1) The combined p-value of all statistical tests using Holm's Method conducted for 36 card decks is greater than the minimum value of 0.05 which indicates that the randomness of the observed data falls within 95% confidence limits.

2) Since the number of games played each month using 36 card decks is small, the number of samples available this month as well as a few previous months were insufficient to perform a meaningful statistical analysis. Hence the analysis performed this month was done using the cumulative data for the last 4 months - i.e Jan 2023 to Apr 2023.

The final outcome of the analysis of 36 cards deck indicates that the RNG is working correctly.

5. Conclusion

Analysis of actual data from game logs for 'Hand Types, 'Ranks' and 'Suits' for **52-card decks** and **36-card decks** indicated statistical randomness.

iTech Labs has done limited sanity checks to verify the integrity of the game logs. iTech Labs also maintains a copy of the game logs for verification purposes. There were a large enough number of game records to give the calculations sufficient statistical power.

We conclude that the Random Number Generator (RNG) is working correctly.

Please click here to see the Original report.

Signed:

Kiren Sreekumar
Principal Consultant
iTech Labs Australia
Date: 04 July 2023

Signed:

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Disclaimer.
While it is not possible to test all possible scenarios in a laboratory environment, iTech Labs has conducted a level of testing appropriate for a component test of this type.