



Blackjack Cards Analysis – January 2023

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **January 01, 2023 to January 31, 2023** as recorded by the respective game servers. The game logs were for blackjack games using 8 decks. iTech Labs has analysed the blackjack 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. Blackjack hand value

Blackjack hand value analysis involved creating subsets of data and conducting Chi-square tests on each subset. Opening hands are the value of the first two cards dealt. Final hand value is the hand value at the end of the game. Dealer final hand value is based on the fixed rules of the game. Player final hand value is dependent on player strategy choice, so has no theoretical basis for comparison.

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 blackjack opening hand value statistics tests.

1.1 Player's opening score (from first two cards):

Test No.	DOF	ChiSqr	P-Value
1	17	18.13	0.38093
2	17	27.30	0.05379
3	17	13.38	0.71042
4	17	18.84	0.33771
5	17	21.45	0.20683
6	17	22.27	0.17452
7	17	14.28	0.64720
8	17	17.19	0.44177
9	17	27.75	0.04789
10	17	12.58	0.76406
11	17	14.88	0.60396
12	17	17.43	0.42532
13	17	9.97	0.90506
14	17	8.46	0.95575
15	17	15.49	0.56004
16	17	9.40	0.92695
17	17	9.73	0.91454
18	17	16.42	0.49447
19	17	31.94	0.01531
20	17	8.90	0.94344
21	17	15.34	0.57100
22	17	19.45	0.30317
23	17	13.87	0.67640

24	17	9.14	0.93569
25	17	8.26	0.96075
26	17	20.36	0.25614
27	17	12.38	0.77662
28	17	9.17	0.93490
29	17	27.72	0.04838
30	17	9.26	0.93159
31	17	23.16	0.14408
32	17	12.28	0.78283
33	17	30.69	0.02179
34	17	21.05	0.22384
35	17	13.75	0.68451
36	17	10.17	0.89631
37	17	23.81	0.12480
38	17	12.71	0.75535
39	17	10.68	0.87271
40	17	21.54	0.20321
41	17	14.26	0.64890
42	17	11.23	0.84446
43	17	8.09	0.96458
44	17	16.63	0.47978
45	17	16.33	0.50049
46	17	16.84	0.46494
47	17	21.95	0.18661
48	17	19.22	0.31633
49	17	29.32	0.03167
50	17	24.05	0.11820
51	17	11.11	0.85070
52	17	12.27	0.78341
53	17	30.10	0.02562
54	17	9.56	0.92086
55	17	21.62	0.19998
56	17	14.30	0.64549
57	17	22.14	0.17932
58	17	12.07	0.79609
59	17	18.89	0.33473
60	17	15.91	0.53057
61	17	17.11	0.44669
62	17	19.55	0.29799
63	17	15.89	0.53153
64	17	28.44	0.04010
65	17	12.14	0.79188
66	17	23.19	0.14304
67	17	8.98	0.94083
68	17	32.18	0.01429
69	17	18.17	0.37812
70	17	17.55	0.41761
71	17	24.35	0.11015
72	17	14.37	0.64066
73	17	20.85	0.23312
74	17	10.69	0.87221
75	17	26.30	0.06919
76	17	10.43	0.88441
77	17	13.51	0.70130
78	17	18.63	0.35029

79	17	14.53	0.62909
80	17	13.58	0.69683
81	17	18.20	0.37617
82	17	13.09	0.73024
83	17	7.47	0.97669
84	17	17.13	0.44547
85	17	15.68	0.54630
86	17	24.69	0.10180
87	17	20.06	0.27098
88	17	18.67	0.34782
89	17	24.26	0.11243
90	17	7.29	0.97941
91	17	20.95	0.22875
92	17	8.42	0.95680
93	17	21.47	0.20611
94	17	12.88	0.74438
95	17	15.13	0.58637
96	17	23.92	0.12149
97	17	10.55	0.87903
98	17	12.28	0.78302
99	17	8.29	0.96005
100	17	7.27	0.97973
Combined P-value for all tests (Using KS method)			0.34725

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 Dealer's opening score (from first two cards):

Test No.	DOF	ChiSqr	P-Value
1	17	28.87	0.03578
2	17	10.68	0.87284
3	17	18.18	0.37757
4	17	18.10	0.38279
5	17	18.43	0.36194
6	17	18.09	0.38311
7	17	17.92	0.39393
8	17	22.99	0.14949
9	17	17.25	0.43778
10	17	12.98	0.73758
11	17	13.23	0.72048
12	17	17.26	0.43716
13	17	28.29	0.04168
14	17	28.14	0.04329
15	17	22.69	0.15946
16	17	11.65	0.82059
17	17	23.22	0.14230
18	17	17.01	0.45383
19	17	12.78	0.75055
20	17	9.85	0.90992
21	17	17.25	0.43730
22	17	19.01	0.32820
23	17	23.74	0.12660

24	17	25.85	0.07714
25	17	22.10	0.18101
26	17	22.55	0.16460
27	17	15.88	0.53256
28	17	17.00	0.45423
29	17	18.47	0.36008
30	17	12.67	0.75798
31	17	14.15	0.65650
32	17	17.62	0.41305
33	17	13.02	0.73466
34	17	14.15	0.65635
35	17	10.18	0.89573
36	17	9.89	0.90808
37	17	23.59	0.13100
38	17	30.84	0.02087
39	17	20.59	0.24523
40	17	13.91	0.67353
41	17	23.14	0.14462
42	17	24.35	0.11013
43	17	14.76	0.61263
44	17	19.96	0.27641
45	17	11.55	0.82664
46	17	13.82	0.67983
47	17	14.97	0.59766
48	17	17.44	0.42499
49	17	25.51	0.08376
50	17	16.78	0.46919
51	17	18.49	0.35838
52	17	8.67	0.95001
53	17	26.26	0.06985
54	17	30.47	0.02317
55	17	21.46	0.20632
56	17	15.15	0.58438
57	17	11.55	0.82666
58	17	20.82	0.23428
59	17	16.82	0.46657
60	17	14.74	0.61422
61	17	12.63	0.76077
62	17	21.73	0.19532
63	17	15.92	0.52965
64	17	20.76	0.23713
65	17	17.65	0.41130
66	17	26.80	0.06114
67	17	10.19	0.89552
68	17	22.93	0.15139
69	17	29.20	0.03269
70	17	16.91	0.46024
71	17	22.92	0.15176
72	17	19.46	0.30255
73	17	12.97	0.73792
74	17	17.33	0.43207
75	17	28.29	0.04162
76	17	16.59	0.48279
77	17	17.97	0.39061
78	17	23.36	0.13794

79	17	15.90	0.53110
80	17	34.62	0.00698
81	17	9.75	0.91388
82	17	21.07	0.22331
83	17	19.75	0.28713
84	17	23.95	0.12077
85	17	10.45	0.88390
86	17	14.12	0.65874
87	17	24.71	0.10142
88	17	11.08	0.85239
89	17	31.75	0.01616
90	17	24.79	0.09944
91	17	19.21	0.31677
92	17	22.88	0.15332
93	17	19.94	0.27721
94	17	21.01	0.22566
95	17	18.75	0.34284
96	17	24.55	0.10535
97	17	17.09	0.44850
98	17	14.85	0.60631
99	17	16.73	0.47265
100	17	11.24	0.84378
Combined P-value for all tests (Using KS method)			0.00314

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.

1.3 Dealer's final score (total of all cards for hands with 3 or more cards):

Test No.	DOF	ChiSqr	P-Value
1	50	60.53	0.14626
2	50	40.29	0.83512
3	50	50.06	0.47091
4	50	55.74	0.26764
5	50	67.35	0.05131
6	50	57.63	0.21377
7	50	55.18	0.28511
8	50	52.03	0.39477
9	50	53.75	0.33283
10	50	54.99	0.29134
11	50	63.92	0.08918
12	50	47.11	0.59016
13	50	49.22	0.50481
14	50	42.84	0.75352
15	50	62.84	0.10497
16	50	82.01	0.00289
17	50	45.49	0.65476
18	50	49.01	0.51291
19	50	34.57	0.95248
20	50	52.15	0.39044
21	50	63.96	0.08862
22	50	48.55	0.53186
23	50	59.01	0.17935

24	50	66.86	0.05574
25	50	27.75	0.99549
26	50	71.98	0.02253
27	50	35.94	0.93269
28	50	50.15	0.46754
29	50	49.96	0.47503
30	50	54.37	0.31157
31	50	50.51	0.45338
32	50	46.98	0.59551
33	50	48.90	0.51773
34	50	47.24	0.58463
35	50	44.71	0.68507
36	50	48.67	0.52700
37	50	27.88	0.99524
38	50	51.36	0.42035
39	50	35.40	0.94113
40	50	49.48	0.49401
41	50	52.04	0.39451
42	50	48.99	0.51372
43	50	36.13	0.92951
44	50	44.05	0.70975
45	50	37.59	0.90201
46	50	36.68	0.91991
47	50	59.70	0.16365
48	50	46.01	0.63403
49	50	67.87	0.04701
50	50	48.83	0.52016
51	50	45.34	0.66064
52	50	57.50	0.21731
53	50	51.51	0.41435
54	50	64.67	0.07935
55	50	43.37	0.73470
56	50	37.36	0.90688
57	50	48.73	0.52446
58	50	42.07	0.78000
59	50	31.12	0.98335
60	50	45.86	0.64001
61	50	43.11	0.74409
62	50	45.39	0.65875
63	50	43.53	0.72896
64	50	51.34	0.42098
65	50	43.54	0.72876
66	50	34.99	0.94694
67	50	37.12	0.91151
68	50	65.24	0.07253
69	50	52.71	0.36955
70	50	42.65	0.76023
71	50	62.81	0.10548
72	50	46.34	0.62118
73	50	49.71	0.48479
74	50	48.77	0.52283
75	50	49.84	0.47965
76	50	54.50	0.30750
77	50	57.78	0.20975
78	50	51.15	0.42841

79	50	59.69	0.16392
80	50	58.60	0.18925
81	50	40.29	0.83511
82	50	39.81	0.84847
83	50	39.16	0.86553
84	50	64.27	0.08448
85	50	68.76	0.04031
86	50	27.52	0.99593
87	50	31.98	0.97782
88	50	51.23	0.42531
89	50	34.17	0.95738
90	50	44.30	0.70053
91	50	37.24	0.90927
92	50	41.14	0.80959
93	50	30.02	0.98876
94	50	57.53	0.21642
95	50	49.08	0.51037
96	50	59.67	0.16438
97	50	62.76	0.10621
98	50	40.67	0.82388
99	50	42.27	0.77304
100	50	59.17	0.17577
Combined P-value for all tests			0.66161

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. Blackjack rank statistics

The blackjack rank analysis aims to establish that the rank of the cards to player and dealer was equally distributed in one of the 13 possible ranks (2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K, A).

The blackjack 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 Blackjack rank statistics for all player cards:

Test No.	DOF	ChiSqr	P-Value
1	12	12.88	0.37778
2	12	18.96	0.08942
3	12	5.18	0.95166
4	12	3.81	0.98662
5	12	15.71	0.20490
6	12	5.90	0.92097
7	12	7.60	0.81587
8	12	9.81	0.63299
9	12	16.24	0.18067
10	12	6.15	0.90809
11	12	5.48	0.93990
12	12	11.78	0.46356
13	12	8.71	0.72721
14	12	8.62	0.73528
15	12	9.01	0.70178

16	12	17.81	0.12158
17	12	7.25	0.84055
18	12	9.34	0.67384
19	12	17.45	0.13359
20	12	5.37	0.94455
21	12	12.30	0.42214
22	12	8.22	0.76763
23	12	11.15	0.51581
24	12	15.82	0.19983
25	12	8.38	0.75491
26	12	15.41	0.22000
27	12	13.81	0.31298
28	12	6.12	0.90991
29	12	14.94	0.24483
30	12	23.19	0.02614
31	12	13.34	0.34461
32	12	5.65	0.93271
33	12	16.26	0.17978
34	12	5.70	0.93060
35	12	19.42	0.07897
36	12	10.07	0.60981
37	12	16.02	0.19050
38	12	8.64	0.73342
39	12	2.71	0.99729
40	12	5.65	0.93274
41	12	8.60	0.73698
42	12	8.76	0.72337
43	12	4.33	0.97665
44	12	3.59	0.98981
45	12	9.86	0.62800
46	12	9.32	0.67550
47	12	12.03	0.44347
48	12	9.55	0.65498
49	12	14.07	0.29651
50	12	18.10	0.11275
51	12	16.02	0.19030
52	12	11.39	0.49546
53	12	22.21	0.03527
54	12	15.46	0.21726
55	12	9.44	0.66486
56	12	9.62	0.64968
57	12	17.29	0.13903
58	12	6.84	0.86832
59	12	4.98	0.95878
60	12	12.57	0.40111
61	12	7.17	0.84589
62	12	16.50	0.16936
63	12	10.67	0.55696
64	12	19.06	0.08703
65	12	9.91	0.62409
66	12	10.26	0.59336
67	12	15.68	0.20655
68	12	10.54	0.56902
69	12	11.62	0.47664
70	12	10.94	0.53445

71	12	14.06	0.29682
72	12	13.24	0.35186
73	12	14.97	0.24319
74	12	6.88	0.86575
75	12	9.94	0.62137
76	12	6.77	0.87235
77	12	14.31	0.28139
78	12	7.14	0.84800
79	12	8.38	0.75512
80	12	6.74	0.87456
81	12	12.12	0.43581
82	12	5.25	0.94895
83	12	8.59	0.73785
84	12	7.69	0.80892
85	12	11.70	0.47036
86	12	12.33	0.41939
87	12	18.06	0.11377
88	12	14.19	0.28892
89	12	5.76	0.92788
90	12	11.45	0.49086
91	12	5.32	0.94638
92	12	6.57	0.88440
93	12	13.23	0.35233
94	12	16.92	0.15260
95	12	13.02	0.36740
96	12	12.50	0.40676
97	12	5.35	0.94522
98	12	20.68	0.05527
99	12	5.72	0.92974
100	12	17.22	0.14157
Combined P-value for all tests (Using KS method)			0.16268

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 Blackjack rank statistics for all dealer cards:

Test No.	DOF	ChiSqr	P-Value
1	12	12.32	0.42039
2	12	11.62	0.47669
3	12	8.17	0.77145
4	12	9.94	0.62123
5	12	22.33	0.03401
6	12	10.61	0.56256
7	12	16.11	0.18609
8	12	4.32	0.97696
9	12	5.90	0.92110
10	12	8.40	0.75321
11	12	15.01	0.24107
12	12	11.97	0.44786
13	12	14.81	0.25192
14	12	18.60	0.09862
15	12	6.59	0.88337

16	12	8.59	0.73759
17	12	3.82	0.98654
18	12	10.27	0.59211
19	12	12.34	0.41916
20	12	7.73	0.80560
21	12	16.39	0.17399
22	12	3.35	0.99253
23	12	12.52	0.40464
24	12	13.99	0.30120
25	12	11.99	0.44668
26	12	12.09	0.43828
27	12	17.76	0.12317
28	12	9.14	0.69086
29	12	14.59	0.26479
30	12	24.22	0.01901
31	12	10.75	0.55079
32	12	11.97	0.44824
33	12	6.64	0.88022
34	12	11.79	0.46293
35	12	17.21	0.14171
36	12	8.97	0.70584
37	12	13.74	0.31758
38	12	11.04	0.52511
39	12	14.62	0.26261
40	12	12.44	0.41101
41	12	13.18	0.35634
42	12	15.19	0.23137
43	12	11.04	0.52518
44	12	10.60	0.56341
45	12	15.48	0.21643
46	12	14.60	0.26400
47	12	8.89	0.71259
48	12	7.82	0.79899
49	12	12.81	0.38265
50	12	13.98	0.30182
51	12	9.06	0.69744
52	12	12.94	0.37352
53	12	11.83	0.45930
54	12	17.59	0.12860
55	12	8.39	0.75400
56	12	7.99	0.78617
57	12	6.19	0.90596
58	12	16.84	0.15553
59	12	9.51	0.65874
60	12	8.55	0.74060
61	12	7.77	0.80298
62	12	12.30	0.42207
63	12	12.09	0.43860
64	12	15.86	0.19764
65	12	5.31	0.94683
66	12	20.80	0.05342
67	12	13.35	0.34423
68	12	5.60	0.93472
69	12	9.26	0.68029
70	12	5.67	0.93158

71	12	10.11	0.60632
72	12	7.73	0.80584
73	12	6.01	0.91557
74	12	9.70	0.64222
75	12	6.65	0.88009
76	12	18.13	0.11177
77	12	16.75	0.15907
78	12	7.89	0.79372
79	12	12.19	0.43017
80	12	15.95	0.19357
81	12	14.94	0.24446
82	12	12.70	0.39150
83	12	3.84	0.98610
84	12	7.30	0.83750
85	12	7.55	0.81937
86	12	10.89	0.53815
87	12	8.87	0.71367
88	12	9.87	0.62700
89	12	10.75	0.55040
90	12	8.36	0.75662
91	12	6.50	0.88880
92	12	11.35	0.49949
93	12	6.96	0.85996
94	12	9.12	0.69302
95	12	4.75	0.96579
96	12	6.49	0.88918
97	12	8.28	0.76326
98	12	15.98	0.19233
99	12	22.73	0.03012
100	12	10.66	0.55853
Combined P-value for all tests (Using KS method)			0.45401

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.

4. Summary of the analysis of blackjack tests

The Blackjack cards analysis completes by combining the result of the KS Test performed in the two types of analysis (Hand Values and Ranks) for 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
Opening Score (Player)	0.34725	1.00000
Opening Score (Dealer)	0.00314	0.01571
Dealer's Final Score	0.66161	1.00000
Player Cards Rank	0.16268	0.65071
Dealer Cards Rank	0.45401	1.00000
Combined P-Value using Holm's Method		0.01571

Notes:

Notes:

Truly random numbers are expected to produce patterns occasionally. '95% confidence tests' should report a failure 5% of the time if the input is truly random. We investigate each 'fail' to ensure they do not repeat more often than the expected 5% of the time.

Our overall result for this period was a 'fail', due to a failing Dealer Opening Score cards test. 100 further chi-square tests were conducted, and only 5 of the 100 tests 'failed', which matched statistical expectation. Hence our conclusion is that the failure observed is a chance occurrence and does not indicate any systemic failure.

The final outcome of the analysis of blackjack indicates that the RNG is working correctly.

5. Conclusion

Analysis of actual data from game logs for 'player opening score', 'dealer opening score', 'dealer final score', 'player card rank' and 'dealer card rank' indicated statistical randomness. The results were satisfactory for 8 deck blackjack.

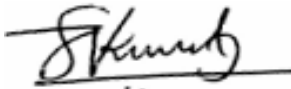
We conclude that the Random Number Generator (RNG) is working correctly.

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.

The scope of the review did not include reviews of financial controls or casino operations. We believe that the probabilities were calculated correctly from the game logs.

Please click here to see the [Original](#) report.

Signed:



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Date: 09 March 2023

Signed:



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Date: 09 March 2023

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.