



Blackjack Cards Analysis – February 2023

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **February 01, 2023 to February 28, 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	25.76	0.07888
2	17	10.03	0.90223
3	17	10.14	0.89758
4	17	39.18	0.00169
5	17	14.84	0.60667
6	17	15.15	0.58482
7	17	22.00	0.18484
8	17	20.28	0.26016
9	17	19.59	0.29559
10	17	21.67	0.19786
11	17	19.91	0.27869
12	17	11.48	0.83074
13	17	21.26	0.21469
14	17	15.94	0.52804
15	17	18.71	0.34541
16	17	13.64	0.69236
17	17	16.17	0.51195
18	17	15.80	0.53810
19	17	29.67	0.02879
20	17	15.52	0.55817
21	17	21.40	0.20878
22	17	14.52	0.62972
23	17	14.21	0.65208

24	17	12.21	0.78755
25	17	16.09	0.51751
26	17	29.80	0.02786
27	17	14.31	0.64517
28	17	19.88	0.28016
29	17	10.93	0.85999
30	17	20.07	0.27089
31	17	14.92	0.60092
32	17	17.66	0.41087
33	17	13.74	0.68512
34	17	18.09	0.38346
35	17	11.65	0.82072
36	17	14.13	0.65823
37	17	23.07	0.14691
38	17	10.93	0.86009
39	17	17.12	0.44597
40	17	27.22	0.05485
41	17	21.32	0.21248
42	17	33.51	0.00971
43	17	12.77	0.75149
44	17	11.69	0.81869
45	17	13.48	0.70353
46	17	29.42	0.03082
47	17	13.48	0.70368
48	17	8.59	0.95238
49	17	15.24	0.57789
50	17	9.10	0.93699
51	17	24.74	0.10071
52	17	14.07	0.66217
53	17	12.82	0.74842
54	17	14.38	0.64014
55	17	24.20	0.11417
56	17	17.56	0.41733
57	17	9.53	0.92214
58	17	13.15	0.72582
59	17	23.59	0.13109
60	17	29.26	0.03222
61	17	29.75	0.02819
62	17	14.31	0.64514
63	17	18.00	0.38878
64	17	20.19	0.26482
65	17	20.32	0.25808
66	17	19.90	0.27947
67	17	14.88	0.60433
68	17	17.49	0.42157
69	17	19.23	0.31554
70	17	17.08	0.44928
71	17	22.82	0.15517
72	17	17.71	0.40755
73	17	13.31	0.71518
74	17	6.31	0.99088
75	17	9.76	0.91356
76	17	11.54	0.82703
77	17	18.29	0.37059

78	17	9.85	0.90983
79	17	20.81	0.23509
80	17	17.87	0.39689
81	17	9.62	0.91889
82	17	19.59	0.29581
83	17	17.77	0.40369
84	17	13.87	0.67642
85	17	14.33	0.64397
86	17	15.03	0.59352
87	17	23.01	0.14878
88	17	10.60	0.87657
89	17	18.52	0.35659
90	17	13.38	0.71008
91	17	11.40	0.83481
92	17	12.83	0.74749
93	17	27.98	0.04521
94	17	21.49	0.20512
95	17	10.34	0.88867
96	17	14.79	0.61073
97	17	20.96	0.22823
98	17	30.03	0.02616
99	17	18.17	0.37794
100	17	15.41	0.56626
Combined P-value for all tests (Using KS method)			0.96912

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	11.17	0.84751
2	17	16.65	0.47820
3	17	21.87	0.18989
4	17	23.25	0.14143
5	17	18.25	0.37325
6	17	17.48	0.42216
7	17	10.75	0.86919
8	17	10.62	0.87566
9	17	18.98	0.32940
10	17	8.19	0.96235
11	17	19.89	0.28008
12	17	30.99	0.02002
13	17	42.58	0.00055
14	17	19.11	0.32198
15	17	13.60	0.69548
16	17	25.81	0.07802
17	17	15.27	0.57631
18	17	15.97	0.52630
19	17	9.84	0.91033
20	17	16.21	0.50896
21	17	16.62	0.48062
22	17	8.89	0.94358

23	17	17.35	0.43118
24	17	12.10	0.79424
25	17	7.78	0.97099
26	17	24.59	0.10415
27	17	12.94	0.74030
28	17	21.20	0.21747
29	17	10.12	0.89840
30	17	14.61	0.62373
31	17	11.31	0.83996
32	17	14.20	0.65257
33	17	30.33	0.02406
34	17	15.61	0.55151
35	17	10.67	0.87303
36	17	16.45	0.49189
37	17	25.22	0.08996
38	17	23.30	0.13962
39	17	24.89	0.09720
40	17	12.95	0.73938
41	17	14.06	0.66281
42	17	10.20	0.89519
43	17	15.60	0.55269
44	17	15.33	0.57190
45	17	17.76	0.40411
46	17	20.64	0.24296
47	17	9.83	0.91060
48	17	21.23	0.21612
49	17	16.50	0.48899
50	17	23.43	0.13572
51	17	16.72	0.47322
52	17	13.13	0.72771
53	17	17.39	0.42816
54	17	26.69	0.06277
55	17	17.35	0.43112
56	17	26.77	0.06152
57	17	28.96	0.03494
58	17	11.68	0.81892
59	17	8.43	0.95649
60	17	33.75	0.00904
61	17	8.94	0.94224
62	17	13.24	0.71985
63	17	17.58	0.41567
64	17	12.70	0.75614
65	17	4.08	0.99941
66	17	25.62	0.08167
67	17	13.75	0.68469
68	17	28.00	0.04498
69	17	12.00	0.79995
70	17	12.76	0.75232
71	17	17.64	0.41219
72	17	19.99	0.27481
73	17	10.96	0.85860
74	17	16.96	0.45685
75	17	24.98	0.09519
76	17	12.48	0.77043

77	17	10.82	0.86565
78	17	21.27	0.21431
79	17	20.13	0.26739
80	17	20.28	0.26030
81	17	11.12	0.85017
82	17	16.55	0.48553
83	17	12.00	0.80041
84	17	25.47	0.08462
85	17	10.44	0.88421
86	17	13.43	0.70727
87	17	18.97	0.33017
88	17	14.47	0.63336
89	17	14.39	0.63964
90	17	12.24	0.78557
91	17	15.29	0.57491
92	17	28.38	0.04069
93	17	9.82	0.91090
94	17	18.99	0.32911
95	17	23.92	0.12174
96	17	14.69	0.61775
97	17	24.66	0.10263
98	17	14.47	0.63363
99	17	16.56	0.48445
100	17	24.32	0.11111
Combined P-value for all tests (Using KS method)			0.72015

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	46.76	0.60423
2	50	50.61	0.44923
3	50	60.13	0.15459
4	50	52.72	0.36941
5	50	47.73	0.56501
6	50	42.52	0.76453
7	50	59.86	0.16031
8	50	58.88	0.18239
9	50	38.52	0.88126
10	50	53.63	0.33699
11	50	26.71	0.99718
12	50	41.80	0.78887
13	50	47.21	0.58609
14	50	68.44	0.04261
15	50	47.09	0.59072
16	50	49.43	0.49634
17	50	37.09	0.91213
18	50	46.23	0.62525
19	50	43.14	0.74296
20	50	58.43	0.19337
21	50	46.78	0.60325

22	50	41.50	0.79830
23	50	44.09	0.70854
24	50	72.45	0.02061
25	50	50.95	0.43609
26	50	64.05	0.08746
27	50	49.51	0.49311
28	50	40.26	0.83587
29	50	48.56	0.53139
30	50	56.66	0.24040
31	50	41.16	0.80895
32	50	69.87	0.03311
33	50	52.67	0.37102
34	50	39.85	0.84724
35	50	78.19	0.00658
36	50	40.95	0.81545
37	50	37.95	0.89443
38	50	42.09	0.77913
39	50	31.51	0.98099
40	50	74.76	0.01322
41	50	36.79	0.91793
42	50	69.41	0.03595
43	50	41.11	0.81070
44	50	61.16	0.13389
45	50	53.77	0.33205
46	50	45.57	0.65138
47	50	38.48	0.88231
48	50	62.18	0.11572
49	50	47.83	0.56079
50	50	46.56	0.61240
51	50	67.67	0.04859
52	50	48.52	0.53306
53	50	44.22	0.70361
54	50	43.99	0.71222
55	50	52.61	0.37336
56	50	51.74	0.40575
57	50	35.53	0.93910
58	50	57.69	0.21235
59	50	57.46	0.21838
60	50	39.96	0.84444
61	50	63.12	0.10069
62	50	28.55	0.99367
63	50	43.91	0.71509
64	50	52.07	0.39313
65	50	48.93	0.51636
66	50	59.18	0.17536
67	50	56.39	0.24843
68	50	79.08	0.00545
69	50	27.59	0.99580
70	50	65.64	0.06807
71	50	54.99	0.29141
72	50	58.08	0.20202
73	50	42.91	0.75126
74	50	49.73	0.48430
75	50	47.44	0.57684

76	50	56.59	0.24257
77	50	35.84	0.93438
78	50	58.77	0.18504
79	50	48.66	0.52738
80	50	76.72	0.00892
81	50	46.98	0.59544
82	50	53.24	0.35071
83	50	29.45	0.99092
84	50	58.65	0.18794
85	50	45.27	0.66341
86	50	55.18	0.28528
87	50	46.61	0.61040
88	50	40.03	0.84241
89	50	62.03	0.11828
90	50	48.76	0.52314
91	50	67.64	0.04888
92	50	46.54	0.61318
93	50	53.14	0.35406
94	50	37.93	0.89480
95	50	48.00	0.55410
96	50	49.96	0.47504
97	50	49.51	0.49298
98	50	53.29	0.34900
99	50	54.36	0.31185
100	50	45.33	0.66117
Combined P-value for all tests			0.99508

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	7.99	0.78614
2	12	12.38	0.41604
3	12	8.77	0.72239
4	12	6.18	0.90667
5	12	8.07	0.77947
6	12	21.52	0.04325
7	12	14.91	0.24645
8	12	5.96	0.91804
9	12	11.50	0.48692
10	12	15.47	0.21660
11	12	13.54	0.33113
12	12	11.75	0.46635

13	12	7.32	0.83606
14	12	13.79	0.31465
15	12	14.98	0.24257
16	12	7.60	0.81591
17	12	35.80	0.00035
18	12	13.22	0.35295
19	12	22.88	0.02879
20	12	9.14	0.69083
21	12	9.52	0.65821
22	12	15.11	0.23536
23	12	5.87	0.92270
24	12	8.21	0.76843
25	12	19.61	0.07475
26	12	19.67	0.07352
27	12	4.98	0.95871
28	12	8.17	0.77155
29	12	13.25	0.35120
30	12	14.11	0.29392
31	12	11.42	0.49329
32	12	13.73	0.31804
33	12	12.44	0.41065
34	12	7.61	0.81468
35	12	5.67	0.93198
36	12	8.36	0.75631
37	12	20.76	0.05400
38	12	5.41	0.94269
39	12	15.32	0.22445
40	12	30.90	0.00204
41	12	15.70	0.20550
42	12	25.31	0.01342
43	12	13.21	0.35400
44	12	14.04	0.29795
45	12	5.26	0.94879
46	12	14.69	0.25857
47	12	5.36	0.94468
48	12	11.70	0.47009
49	12	18.78	0.09405
50	12	14.93	0.24514
51	12	16.05	0.18898
52	12	6.41	0.89376
53	12	8.82	0.71830
54	12	7.82	0.79914
55	12	13.01	0.36867
56	12	21.16	0.04813
57	12	6.25	0.90271
58	12	15.18	0.23176
59	12	12.55	0.40294
60	12	20.36	0.06053
61	12	20.13	0.06459
62	12	16.27	0.17909
63	12	7.93	0.79055
64	12	11.06	0.52350
65	12	9.10	0.69419
66	12	11.61	0.47720

67	12	8.75	0.72428
68	12	4.60	0.97003
69	12	10.06	0.61112
70	12	14.60	0.26412
71	12	16.52	0.16867
72	12	17.07	0.14692
73	12	6.62	0.88148
74	12	5.40	0.94334
75	12	9.99	0.61687
76	12	8.86	0.71506
77	12	5.30	0.94712
78	12	12.85	0.37981
79	12	4.71	0.96704
80	12	11.94	0.45017
81	12	9.37	0.67108
82	12	14.74	0.25616
83	12	8.86	0.71459
84	12	22.55	0.03176
85	12	13.18	0.35605
86	12	22.69	0.03045
87	12	3.88	0.98544
88	12	7.90	0.79301
89	12	17.01	0.14917
90	12	9.98	0.61769
91	12	10.61	0.56245
92	12	11.27	0.50614
93	12	10.21	0.59777
94	12	7.89	0.79345
95	12	13.89	0.30752
96	12	6.60	0.88307
97	12	12.35	0.41765
98	12	21.31	0.04597
99	12	11.38	0.49674
100	12	18.79	0.09377
Combined P-value for all tests (Using KS method)			0.90496

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	12.65	0.39511
2	12	12.55	0.40260
3	12	10.05	0.61156
4	12	15.52	0.21408
5	12	10.70	0.55493
6	12	7.94	0.78986
7	12	17.05	0.14788
8	12	9.79	0.63421
9	12	11.29	0.50412
10	12	8.52	0.74311
11	12	6.79	0.87118

12	12	18.95	0.08964
13	12	5.16	0.95258
14	12	2.76	0.99700
15	12	13.13	0.35939
16	12	15.82	0.19975
17	12	17.73	0.12414
18	12	12.14	0.43433
19	12	9.72	0.64088
20	12	11.56	0.48164
21	12	8.73	0.72619
22	12	21.31	0.04596
23	12	12.49	0.40727
24	12	16.71	0.16077
25	12	9.68	0.64363
26	12	16.47	0.17068
27	12	16.14	0.18474
28	12	8.86	0.71472
29	12	9.28	0.67860
30	12	19.79	0.07114
31	12	10.69	0.55583
32	12	21.10	0.04900
33	12	1.71	0.99974
34	12	8.77	0.72253
35	12	10.63	0.56097
36	12	19.26	0.08240
37	12	9.29	0.67782
38	12	17.01	0.14912
39	12	11.08	0.52183
40	12	9.01	0.70170
41	12	8.13	0.77515
42	12	10.56	0.56739
43	12	8.21	0.76864
44	12	9.64	0.64765
45	12	11.36	0.49800
46	12	4.13	0.98096
47	12	11.37	0.49729
48	12	11.26	0.50688
49	12	18.90	0.09107
50	12	13.86	0.30985
51	12	10.28	0.59102
52	12	12.18	0.43109
53	12	7.56	0.81821
54	12	10.71	0.55423
55	12	17.38	0.13589
56	12	6.37	0.89641
57	12	11.81	0.46094
58	12	9.34	0.67383
59	12	10.15	0.60251
60	12	18.32	0.10637
61	12	13.27	0.34966
62	12	11.86	0.45690
63	12	4.90	0.96133
64	12	16.24	0.18068
65	12	4.10	0.98149

66	12	12.19	0.43067
67	12	12.70	0.39130
68	12	11.25	0.50767
69	12	6.75	0.87370
70	12	10.39	0.58150
71	12	17.25	0.14034
72	12	10.25	0.59402
73	12	9.22	0.68401
74	12	9.09	0.69495
75	12	21.77	0.04022
76	12	6.73	0.87492
77	12	13.42	0.33932
78	12	7.72	0.80693
79	12	14.20	0.28813
80	12	10.73	0.55193
81	12	21.10	0.04894
82	12	6.07	0.91266
83	12	11.72	0.46882
84	12	7.01	0.85678
85	12	5.10	0.95470
86	12	5.91	0.92038
87	12	6.40	0.89433
88	12	10.87	0.53998
89	12	11.68	0.47135
90	12	12.02	0.44422
91	12	21.80	0.03988
92	12	16.95	0.15162
93	12	16.33	0.17638
94	12	6.37	0.89651
95	12	7.34	0.83460
96	12	5.93	0.91933
97	12	12.78	0.38550
98	12	13.21	0.35383
99	12	12.84	0.38076
100	12	15.30	0.22535
Combined P-value for all tests (Using KS method)			0.51482

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)	0.96912	1.00000
Opening Score (Dealer)	0.72015	1.00000
Dealer's Final Score	0.99508	1.00000
Player Cards Rank	0.90496	1.00000
Dealer Cards Rank	0.51482	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 blackjack 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 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.

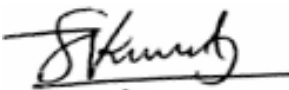
We conclude that the Random Number Generator (RNG) is working correctly.

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:



Kiren Sreekumar
Principal Consultant
iTech Labs Australia
Date: 20 June, 2023

Signed:



Alvin Rizaldi
Senior Consultant
iTech Labs Australia
Date: 20 June, 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.