

Blackjack Cards Analysis – December 2022

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **December 01, 2022 to December 31, 2022** 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	13.26	0.71857
2	17	13.98	0.66874
3	17	15.09	0.58893
4	17	13.35	0.71221
5	17	16.46	0.49123
6	17	17.03	0.45217
7	17	10.57	0.87804
8	17	21.46	0.20644
9	17	20.34	0.25725
10	17	14.10	0.65998
11	17	12.88	0.74448
12	17	16.57	0.48370
13	17	15.42	0.56503
14	17	19.80	0.28476
15	17	13.76	0.68427
16	17	19.56	0.29732
17	17	22.49	0.16671
18	17	17.25	0.43774
19	17	21.51	0.20410
20	17	14.04	0.66424
21	17	17.67	0.41006
22	17	18.23	0.37456
23	17	16.89	0.46211

24	17	13.40	0.70913
25	17	18.14	0.37985
26	17	12.81	0.74882
27	17	15.82	0.53697
28	17	8.70	0.94929
29	17	11.31	0.83973
30	17	25.08	0.09293
31	17	20.57	0.24626
32	17	11.88	0.80748
33	17	19.73	0.28832
34	17	8.52	0.95402
35	17	26.21	0.07064
36	17	17.90	0.39531
37	17	20.67	0.24131
38	17	11.47	0.83131
39	17	23.62	0.13024
40	17	12.71	0.75511
41	17	23.51	0.13345
42	17	12.92	0.74182
43	17	14.73	0.61494
44	17	14.27	0.64796
45	17	10.32	0.88976
46	17	26.80	0.06103
47	17	12.12	0.79252
48	17	24.89	0.09709
49	17	16.46	0.49163
50	17	16.39	0.49605
51	17	14.88	0.60380
52	17	17.31	0.43342
53	17	15.85	0.53446
54	17	21.70	0.19639
55	17	34.41	0.00744
56	17	18.18	0.37776
57	17	17.47	0.42277
58	17	11.29	0.84130
59	17	12.37	0.77722
60	17	20.55	0.24708
61	17	14.74	0.61445
62	17	14.12	0.65829
63	17	11.41	0.83423
64	17	14.56	0.62726
65	17	20.64	0.24285
66	17	14.03	0.66529
67	17	13.13	0.72748
68	17	11.87	0.80812
69	17	18.23	0.37429
70	17	16.11	0.51625
71	17	21.02	0.22539
72	17	7.38	0.97809
73	17	14.90	0.60235
74	17	27.14	0.05610
75	17	10.65	0.87433
76	17	22.66	0.16076
77	17	15.47	0.56184
78	17	9.07	0.93814

79	17	26.42	0.06718
80	17	14.79	0.61030
81	17	33.39	0.01006
82	17	15.70	0.54487
83	17	25.76	0.07894
84	17	20.51	0.24893
85	17	17.73	0.40623
86	17	5.72	0.99485
87	17	9.61	0.91918
88	17	14.57	0.62659
89	17	17.97	0.39051
90	17	13.31	0.71491
91	17	16.21	0.50870
92	17	11.52	0.82832
93	17	18.40	0.36384
94	17	17.38	0.42874
95	17	26.44	0.06680
96	17	16.33	0.50057
97	17	19.59	0.29563
98	17	16.20	0.50962
99	17	20.45	0.25200
100	17	14.27	0.64759
Combined P-value for all tests (Using KS method)			0.62275

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	18.06	0.38527
2	17	14.10	0.65996
3	17	12.34	0.77897
4	17	17.63	0.41226
5	17	21.41	0.20838
6	17	17.17	0.44281
7	17	17.52	0.41986
8	17	10.34	0.88862
9	17	17.92	0.39370
10	17	26.65	0.06337
11	17	15.58	0.55391
12	17	10.12	0.89861
13	17	19.07	0.32454
14	17	20.31	0.25844
15	17	20.23	0.26253
16	17	25.56	0.08293
17	17	11.86	0.80857
18	17	24.28	0.11192
19	17	18.62	0.35077
20	17	22.67	0.16037
21	17	12.00	0.80034
22	17	20.51	0.24880
23	17	9.79	0.91217

24	17	6.25	0.99135
25	17	11.02	0.85564
26	17	16.60	0.48203
27	17	11.44	0.83270
28	17	15.48	0.56077
29	17	19.98	0.27510
30	17	14.82	0.60811
31	17	6.68	0.98738
32	17	16.32	0.50110
33	17	20.45	0.25197
34	17	14.68	0.61838
35	17	16.92	0.45955
36	17	10.28	0.89132
37	17	19.00	0.32846
38	17	12.13	0.79225
39	17	31.01	0.01992
40	17	8.11	0.96414
41	17	20.14	0.26694
42	17	16.09	0.51760
43	17	29.29	0.03196
44	17	4.39	0.99904
45	17	27.72	0.04838
46	17	14.81	0.60892
47	17	16.94	0.45841
48	17	9.05	0.93876
49	17	14.37	0.64100
50	17	18.06	0.38505
51	17	8.64	0.95098
52	17	5.06	0.99759
53	17	27.43	0.05210
54	17	14.39	0.63945
55	17	25.14	0.09159
56	17	7.57	0.97488
57	17	10.73	0.87005
58	17	24.10	0.11684
59	17	24.23	0.11328
60	17	8.95	0.94192
61	17	18.39	0.36475
62	17	23.37	0.13753
63	17	14.39	0.63960
64	17	13.01	0.73523
65	17	10.44	0.88420
66	17	16.34	0.49960
67	17	11.71	0.81723
68	17	25.68	0.08058
69	17	14.55	0.62818
70	17	19.50	0.30036
71	17	23.88	0.12282
72	17	13.58	0.69684
73	17	15.58	0.55366
74	17	18.43	0.36227
75	17	9.13	0.93605
76	17	11.06	0.85324
77	17	14.83	0.60782
78	17	23.88	0.12274

79	17	24.41	0.10864
80	17	17.15	0.44447
81	17	15.01	0.59450
82	17	20.28	0.26036
83	17	5.37	0.99653
84	17	17.67	0.40966
85	17	15.19	0.58151
86	17	17.82	0.40055
87	17	19.60	0.29494
88	17	24.69	0.10187
89	17	21.00	0.22611
90	17	16.26	0.50533
91	17	18.08	0.38392
92	17	7.65	0.97346
93	17	16.10	0.51701
94	17	12.62	0.76116
95	17	19.49	0.30110
96	17	17.70	0.40777
97	17	22.63	0.16163
98	17	12.88	0.74404
99	17	7.30	0.97933
100	17	15.81	0.53747
Combined P-value for all tests (Using KS method)			0.76186

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	51.56	0.41260
2	50	61.19	0.13335
3	50	53.65	0.33606
4	50	74.21	0.01470
5	50	41.53	0.79733
6	50	47.39	0.57861
7	50	54.92	0.29355
8	50	50.00	0.47338
9	50	61.29	0.13149
10	50	66.09	0.06325
11	50	49.78	0.48233
12	50	44.51	0.69254
13	50	44.98	0.67470
14	50	49.91	0.47696
15	50	34.04	0.95893
16	50	49.55	0.49149
17	50	33.51	0.96461
18	50	53.85	0.32945
19	50	57.44	0.21882
20	50	54.90	0.29432
21	50	28.32	0.99425
22	50	42.37	0.76991
23	50	58.73	0.18612

24	50	50.36	0.45930
25	50	58.77	0.18501
26	50	59.09	0.17752
27	50	54.48	0.30806
28	50	69.59	0.03480
29	50	49.15	0.50762
30	50	43.91	0.71522
31	50	32.47	0.97409
32	50	53.56	0.33926
33	50	62.66	0.10790
34	50	54.22	0.31666
35	50	49.69	0.48587
36	50	42.61	0.76172
37	50	43.05	0.74629
38	50	60.54	0.14608
39	50	43.37	0.73482
40	50	50.93	0.43681
41	50	54.57	0.30505
42	50	44.43	0.69573
43	50	63.60	0.09360
44	50	42.34	0.77091
45	50	57.46	0.21838
46	50	36.74	0.91887
47	50	31.67	0.97999
48	50	56.38	0.24869
49	50	44.87	0.67868
50	50	59.16	0.17592
51	50	53.56	0.33936
52	50	43.18	0.74148
53	50	53.94	0.32626
54	50	43.47	0.73111
55	50	57.38	0.22047
56	50	50.51	0.45337
57	50	47.81	0.56184
58	50	49.70	0.48553
59	50	30.23	0.98785
60	50	34.40	0.95467
61	50	81.01	0.00360
62	50	52.44	0.37943
63	50	48.30	0.54203
64	50	56.35	0.24950
65	50	58.00	0.20421
66	50	42.68	0.75925
67	50	31.64	0.98013
68	50	35.51	0.93950
69	50	42.67	0.75931
70	50	31.93	0.97817
71	50	57.23	0.22465
72	50	31.03	0.98387
73	50	37.71	0.89954
74	50	56.14	0.25585
75	50	40.68	0.82356
76	50	41.72	0.79122
77	50	57.83	0.20852
78	50	39.30	0.86201

79	50	72.52	0.02037
80	50	42.94	0.75013
81	50	37.11	0.91187
82	50	43.86	0.71697
83	50	47.17	0.58753
84	50	52.07	0.39315
85	50	62.53	0.10999
86	50	44.68	0.68600
87	50	47.77	0.56349
88	50	61.44	0.12870
89	50	56.29	0.25126
90	50	57.68	0.21253
91	50	35.97	0.93225
92	50	44.79	0.68195
93	50	63.22	0.09921
94	50	36.63	0.92083
95	50	60.97	0.13762
96	50	41.47	0.79923
97	50	50.60	0.44954
98	50	64.60	0.08031
99	50	63.39	0.09664
100	50	59.25	0.17373
Combined P-value for all tests			0.68510

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	9.15	0.68972
2	12	7.87	0.79500
3	12	9.44	0.66479
4	12	10.19	0.59924
5	12	17.47	0.13262
6	12	5.89	0.92169
7	12	6.44	0.89230
8	12	21.18	0.04783
9	12	12.66	0.39453
10	12	6.38	0.89580
11	12	7.95	0.78913
12	12	9.44	0.66473
13	12	6.88	0.86514
14	12	14.35	0.27908
15	12	13.26	0.35043

16	12	22.61	0.03123
17	12	7.04	0.85496
18	12	12.57	0.40136
19	12	13.16	0.35780
20	12	14.11	0.29366
21	12	4.51	0.97226
22	12	12.23	0.42744
23	12	13.00	0.36880
24	12	7.53	0.82036
25	12	11.56	0.48130
26	12	11.71	0.46913
27	12	12.17	0.43191
28	12	9.15	0.69013
29	12	9.91	0.62421
30	12	5.12	0.95397
31	12	12.76	0.38672
32	12	2.73	0.99717
33	12	9.53	0.65729
34	12	10.25	0.59375
35	12	8.40	0.75287
36	12	7.29	0.83764
37	12	16.73	0.16022
38	12	12.52	0.40451
39	12	12.32	0.41997
40	12	10.13	0.60426
41	12	20.59	0.05675
42	12	13.24	0.35179
43	12	9.93	0.62193
44	12	7.79	0.80162
45	12	2.52	0.99809
46	12	29.71	0.00309
47	12	14.30	0.28194
48	12	7.56	0.81837
49	12	13.92	0.30593
50	12	13.82	0.31244
51	12	11.35	0.49903
52	12	6.76	0.87312
53	12	13.16	0.35751
54	12	8.36	0.75614
55	12	13.01	0.36845
56	12	12.46	0.40947
57	12	17.34	0.13728
58	12	19.88	0.06930
59	12	5.16	0.95235
60	12	16.19	0.18281
61	12	17.20	0.14232
62	12	9.05	0.69886
63	12	13.10	0.36216
64	12	12.75	0.38722
65	12	10.40	0.58117
66	12	17.18	0.14279
67	12	10.17	0.60143
68	12	8.36	0.75614
69	12	8.24	0.76571
70	12	9.81	0.63273

71	12	14.87	0.24871
72	12	8.50	0.74534
73	12	11.13	0.51779
74	12	18.03	0.11474
75	12	4.42	0.97453
76	12	20.38	0.06017
77	12	7.71	0.80707
78	12	7.89	0.79367
79	12	7.91	0.79196
80	12	13.96	0.30321
81	12	10.67	0.55773
82	12	21.83	0.03946
83	12	13.24	0.35169
84	12	12.14	0.43453
85	12	7.11	0.85035
86	12	5.67	0.93196
87	12	13.95	0.30383
88	12	11.09	0.52134
89	12	15.85	0.19802
90	12	5.45	0.94138
91	12	11.08	0.52217
92	12	14.23	0.28618
93	12	15.70	0.20541
94	12	6.33	0.89865
95	12	17.90	0.11884
96	12	6.00	0.91606
97	12	18.36	0.10518
98	12	18.87	0.09161
99	12	15.45	0.21770
100	12	8.17	0.77185
Combined P-value for all tests (Using KS method)			0.71148

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	12.42	0.41264
2	12	9.58	0.65305
3	12	11.18	0.51339
4	12	13.49	0.33437
5	12	13.28	0.34929
6	12	7.19	0.84495
7	12	18.87	0.09179
8	12	6.53	0.88728
9	12	14.09	0.29528
10	12	17.15	0.14419
11	12	13.79	0.31435
12	12	9.46	0.66291
13	12	34.72	0.00052
14	12	6.65	0.87974
15	12	4.56	0.97112

16	12	10.85	0.54209
17	12	13.92	0.30579
18	12	3.59	0.98973
19	12	9.21	0.68500
20	12	6.28	0.90112
21	12	18.80	0.09356
22	12	4.96	0.95926
23	12	15.83	0.19911
24	12	12.71	0.39020
25	12	9.03	0.70056
26	12	8.31	0.76037
27	12	8.90	0.71164
28	12	3.72	0.98793
29	12	8.38	0.75484
30	12	13.51	0.33301
31	12	16.74	0.15982
32	12	9.37	0.67121
33	12	3.45	0.99147
34	12	7.04	0.85471
35	12	7.50	0.82299
36	12	16.64	0.16374
37	12	8.50	0.74508
38	12	12.27	0.42445
39	12	10.18	0.60027
40	12	7.44	0.82710
41	12	6.79	0.87118
42	12	12.63	0.39668
43	12	12.21	0.42884
44	12	6.99	0.85807
45	12	22.80	0.02945
46	12	10.88	0.53952
47	12	9.01	0.70185
48	12	11.14	0.51701
49	12	10.71	0.55403
50	12	7.97	0.78738
51	12	5.03	0.95713
52	12	11.72	0.46808
53	12	5.58	0.93581
54	12	25.69	0.01189
55	12	10.70	0.55460
56	12	15.72	0.20455
57	12	13.14	0.35929
58	12	9.35	0.67293
59	12	20.64	0.05592
60	12	8.35	0.75696
61	12	18.16	0.11106
62	12	8.04	0.78217
63	12	14.18	0.28957
64	12	18.52	0.10086
65	12	11.11	0.51983
66	12	14.37	0.27742
67	12	4.64	0.96900
68	12	11.24	0.50846
69	12	6.87	0.86598
70	12	6.58	0.88428

71	12	8.51	0.74434
72	12	7.99	0.78609
73	12	7.73	0.80564
74	12	14.47	0.27172
75	12	9.83	0.63058
76	12	14.32	0.28052
77	12	15.32	0.22449
78	12	13.64	0.32437
79	12	10.51	0.57109
80	12	15.00	0.24169
81	12	12.58	0.40049
82	12	12.80	0.38349
83	12	17.19	0.14271
84	12	19.22	0.08331
85	12	2.38	0.99855
86	12	15.47	0.21675
87	12	7.25	0.84079
88	12	12.95	0.37255
89	12	8.36	0.75609
90	12	10.26	0.59317
91	12	5.76	0.92775
92	12	8.70	0.72871
93	12	6.88	0.86574
94	12	15.57	0.21176
95	12	11.61	0.47729
96	12	17.54	0.13039
97	12	17.58	0.12910
98	12	14.41	0.27534
99	12	9.52	0.65836
100	12	10.35	0.58554
Combined P-value for all tests (Using KS method)			0.47848

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)	0.62275	1.00000
Opening Score (Dealer)	0.76186	1.00000
Dealer's Final Score	0.68510	1.00000
Player Cards Rank	0.71148	1.00000
Dealer Cards Rank	0.47848	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.

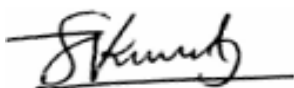
We conclude that the Random Number Generator (RNG) is working correctly.

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 February, 2023

Signed:



Gyulserian Hyusseini
Senior Consultant
iTech Labs Australia
Date: 20 February, 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.