



Blackjack Cards Analysis – April 2022

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **April 01, 2022 to April 30, 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	17.39	0.42797
2	17	19.86	0.28133
3	17	24.74	0.10074
4	17	27.44	0.05193
5	17	21.56	0.20209
6	17	12.75	0.75307
7	17	12.12	0.79261
8	17	19.19	0.31763
9	17	12.93	0.74107
10	17	13.29	0.71651
11	17	15.42	0.56528
12	17	18.03	0.38723
13	17	12.73	0.75393
14	17	13.23	0.72056
15	17	26.15	0.07186
16	17	10.27	0.89198
17	17	8.32	0.95922
18	17	7.88	0.96911
19	17	19.26	0.31376
20	17	27.68	0.04888
21	17	10.96	0.85840
22	17	13.20	0.72240
23	17	14.61	0.62359

24	17	22.65	0.16111
25	17	13.21	0.72221
26	17	10.58	0.87733
27	17	9.20	0.93375
28	17	19.20	0.31703
29	17	13.56	0.69827
30	17	17.93	0.39334
31	17	14.65	0.62044
32	17	20.50	0.24968
33	17	7.89	0.96890
34	17	10.93	0.86002
35	17	21.92	0.18797
36	17	15.34	0.57079
37	17	13.21	0.72209
38	17	11.14	0.84911
39	17	21.05	0.22412
40	17	19.51	0.29983
41	17	16.66	0.47754
42	17	16.91	0.46035
43	17	27.04	0.05755
44	17	21.90	0.18859
45	17	17.38	0.42868
46	17	11.95	0.80327
47	17	13.49	0.70293
48	17	16.53	0.48642
49	17	12.41	0.77452
50	17	23.53	0.13283
51	17	12.83	0.74769
52	17	13.54	0.69958
53	17	12.80	0.74968
54	17	19.85	0.28192
55	17	23.36	0.13797
56	17	14.04	0.66406
57	17	18.60	0.35193
58	17	12.55	0.76571
59	17	15.60	0.55220
60	17	23.52	0.13316
61	17	13.98	0.66860
62	17	10.12	0.89840
63	17	19.40	0.30609
64	17	25.14	0.09168
65	17	14.22	0.65124
66	17	23.41	0.13625
67	17	10.06	0.90108
68	17	22.53	0.16520
69	17	21.94	0.18700
70	17	10.39	0.88642
71	17	24.16	0.11507
72	17	25.69	0.08029
73	17	10.28	0.89158
74	17	9.52	0.92251
75	17	20.15	0.26657
76	17	20.61	0.24441
77	17	18.41	0.36341
78	17	10.04	0.90186

79	17	6.93	0.98442
80	17	10.91	0.86095
81	17	17.79	0.40242
82	17	18.94	0.33177
83	17	17.78	0.40316
84	17	10.62	0.87555
85	17	10.07	0.90080
86	17	30.06	0.02588
87	17	21.69	0.19711
88	17	15.70	0.54524
89	17	12.98	0.73766
90	17	15.38	0.56823
91	17	11.95	0.80329
92	17	10.15	0.89738
93	17	18.14	0.38023
94	17	18.20	0.37631
95	17	22.75	0.15773
96	17	5.32	0.99670
97	17	32.20	0.01420
98	17	12.39	0.77625
99	17	11.39	0.83560
100	17	10.53	0.87982
Combined P-value for all tests (Using KS method)			0.06828

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	16.03	0.52153
2	17	15.49	0.56046
3	17	18.90	0.33452
4	17	23.96	0.12051
5	17	33.11	0.01091
6	17	14.99	0.59651
7	17	16.38	0.49682
8	17	23.04	0.14798
9	17	21.21	0.21706
10	17	11.64	0.82171
11	17	13.11	0.72906
12	17	42.82	0.00051
13	17	16.07	0.51857
14	17	19.61	0.29457
15	17	21.23	0.21609
16	17	13.07	0.73158
17	17	12.73	0.75398
18	17	24.41	0.10873
19	17	10.80	0.86652
20	17	10.96	0.85866
21	17	20.04	0.27197
22	17	15.22	0.57950
23	17	9.40	0.92679

24	17	18.76	0.34272
25	17	13.48	0.70328
26	17	15.97	0.52585
27	17	11.81	0.81172
28	17	21.52	0.20392
29	17	26.25	0.07004
30	17	10.79	0.86712
31	17	11.42	0.83372
32	17	22.56	0.16422
33	17	14.00	0.66675
34	17	13.56	0.69814
35	17	14.96	0.59844
36	17	18.65	0.34881
37	17	19.97	0.27594
38	17	16.55	0.48489
39	17	7.41	0.97764
40	17	12.63	0.76054
41	17	23.14	0.14463
42	17	19.52	0.29946
43	17	24.32	0.11104
44	17	26.88	0.05989
45	17	17.67	0.41025
46	17	28.51	0.03935
47	17	18.87	0.33592
48	17	13.02	0.73456
49	17	22.40	0.16993
50	17	10.26	0.89243
51	17	21.83	0.19117
52	17	13.50	0.70247
53	17	18.68	0.34741
54	17	14.71	0.61604
55	17	8.98	0.94100
56	17	15.52	0.55824
57	17	10.87	0.86335
58	17	21.98	0.18539
59	17	17.55	0.41753
60	17	21.69	0.19676
61	17	11.10	0.85155
62	17	10.95	0.85902
63	17	8.18	0.96256
64	17	15.46	0.56226
65	17	12.85	0.74624
66	17	30.98	0.02007
67	17	8.06	0.96518
68	17	26.61	0.06398
69	17	17.58	0.41583
70	17	12.46	0.77162
71	17	12.55	0.76591
72	17	16.33	0.50090
73	17	8.96	0.94150
74	17	16.62	0.48072
75	17	29.03	0.03427
76	17	17.34	0.43133
77	17	10.73	0.87042
78	17	7.40	0.97772

79	17	13.47	0.70444
80	17	13.71	0.68717
81	17	10.47	0.88271
82	17	23.42	0.13602
83	17	10.08	0.90038
84	17	23.93	0.12145
85	17	11.61	0.82321
86	17	5.19	0.99717
87	17	18.48	0.35909
88	17	20.94	0.22893
89	17	14.76	0.61302
90	17	11.24	0.84376
91	17	20.19	0.26467
92	17	24.06	0.11773
93	17	19.45	0.30335
94	17	16.94	0.45838
95	17	18.44	0.36178
96	17	12.48	0.77052
97	17	9.06	0.93821
98	17	31.72	0.01628
99	17	24.55	0.10517
100	17	28.84	0.03608
Combined P-value for all tests (Using KS method)			0.72724

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	41.16	0.80905
2	50	57.96	0.20527
3	50	56.79	0.23671
4	50	43.22	0.74031
5	50	35.59	0.93828
6	50	60.69	0.14303
7	50	53.28	0.34905
8	50	49.70	0.48546
9	50	53.00	0.35937
10	50	50.87	0.43908
11	50	64.87	0.07692
12	50	31.62	0.98031
13	50	45.85	0.64069
14	50	37.34	0.90714
15	50	52.55	0.37563
16	50	51.73	0.40598
17	50	37.72	0.89925
18	50	57.74	0.21080
19	50	66.86	0.05571
20	50	56.50	0.24503
21	50	30.23	0.98784
22	50	41.09	0.81109
23	50	28.02	0.99493

24	50	60.35	0.14996
25	50	43.50	0.73017
26	50	42.68	0.75909
27	50	35.66	0.93710
28	50	46.69	0.60682
29	50	55.34	0.28016
30	50	56.74	0.23815
31	50	19.13	0.99998
32	50	42.95	0.74972
33	50	56.97	0.23191
34	50	58.93	0.18122
35	50	63.61	0.09350
36	50	40.34	0.83373
37	50	61.86	0.12124
38	50	55.23	0.28365
39	50	53.56	0.33921
40	50	36.03	0.93122
41	50	56.73	0.23844
42	50	59.64	0.16507
43	50	44.49	0.69345
44	50	51.42	0.41806
45	50	61.05	0.13612
46	50	57.37	0.22068
47	50	67.01	0.05431
48	50	60.69	0.14310
49	50	49.99	0.47369
50	50	65.07	0.07450
51	50	38.89	0.87236
52	50	61.04	0.13628
53	50	63.63	0.09324
54	50	34.34	0.95542
55	50	42.13	0.77783
56	50	55.29	0.28170
57	50	65.22	0.07276
58	50	40.93	0.81602
59	50	31.99	0.97775
60	50	43.09	0.74462
61	50	47.43	0.57729
62	50	65.92	0.06499
63	50	62.01	0.11862
64	50	56.32	0.25028
65	50	51.06	0.43166
66	50	53.90	0.32747
67	50	68.77	0.04022
68	50	35.91	0.93325
69	50	64.75	0.07836
70	50	43.34	0.73569
71	50	38.64	0.87848
72	50	57.33	0.22178
73	50	51.19	0.42686
74	50	52.25	0.38671
75	50	37.93	0.89479
76	50	46.12	0.62994
77	50	42.47	0.76638
78	50	39.35	0.86083

79	50	69.30	0.03664
80	50	73.42	0.01715
81	50	66.43	0.05986
82	50	55.57	0.27314
83	50	43.97	0.71286
84	50	56.97	0.23167
85	50	45.61	0.64989
86	50	54.64	0.30265
87	50	43.26	0.73886
88	50	44.96	0.67541
89	50	58.48	0.19222
90	50	41.91	0.78512
91	50	33.64	0.96332
92	50	33.26	0.96714
93	50	31.44	0.98143
94	50	63.28	0.09832
95	50	42.50	0.76517
96	50	48.47	0.53486
97	50	48.19	0.54623
98	50	57.38	0.22051
99	50	57.23	0.22467
100	50	63.76	0.09143
Combined P-value for all tests			0.07546

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	7.74	0.80495
2	12	11.69	0.47072
3	12	11.55	0.48263
4	12	7.34	0.83435
5	12	28.63	0.00447
6	12	6.88	0.86531
7	12	20.26	0.06232
8	12	17.44	0.13364
9	12	11.29	0.50441
10	12	11.48	0.48846
11	12	11.88	0.45569
12	12	8.86	0.71450
13	12	11.34	0.49986
14	12	14.66	0.26067
15	12	16.09	0.18733

16	12	9.88	0.62684
17	12	15.46	0.21734
18	12	8.16	0.77219
19	12	5.64	0.93304
20	12	8.00	0.78544
21	12	12.81	0.38330
22	12	7.99	0.78607
23	12	4.83	0.96348
24	12	10.97	0.53115
25	12	8.75	0.72412
26	12	11.04	0.52584
27	12	7.37	0.83223
28	12	13.57	0.32873
29	12	7.62	0.81437
30	12	16.47	0.17056
31	12	14.64	0.26160
32	12	16.73	0.16004
33	12	7.47	0.82477
34	12	10.80	0.54579
35	12	6.11	0.91064
36	12	15.68	0.20653
37	12	28.53	0.00463
38	12	10.97	0.53183
39	12	3.97	0.98401
40	12	15.36	0.22244
41	12	5.51	0.93858
42	12	10.81	0.54527
43	12	9.13	0.69144
44	12	15.42	0.21927
45	12	18.58	0.09929
46	12	16.09	0.18733
47	12	15.25	0.22805
48	12	14.89	0.24773
49	12	9.94	0.62140
50	12	11.16	0.51509
51	12	14.30	0.28196
52	12	20.03	0.06656
53	12	21.08	0.04928
54	12	8.85	0.71586
55	12	16.89	0.15378
56	12	13.74	0.31762
57	12	22.21	0.03521
58	12	10.96	0.53269
59	12	10.69	0.55583
60	12	11.00	0.52858
61	12	10.90	0.53768
62	12	10.74	0.55167
63	12	3.90	0.98524
64	12	6.05	0.91364
65	12	6.04	0.91385
66	12	17.60	0.12845
67	12	14.25	0.28491
68	12	10.92	0.53561
69	12	12.20	0.42975
70	12	23.14	0.02658

71	12	10.53	0.56922
72	12	10.02	0.61386
73	12	4.31	0.97717
74	12	25.06	0.01456
75	12	8.04	0.78184
76	12	9.25	0.68161
77	12	14.68	0.25964
78	12	10.15	0.60263
79	12	11.07	0.52276
80	12	4.68	0.96771
81	12	9.25	0.68110
82	12	13.91	0.30675
83	12	12.98	0.37050
84	12	11.96	0.44906
85	12	6.22	0.90459
86	12	10.19	0.59947
87	12	10.79	0.54700
88	12	6.80	0.87042
89	12	9.10	0.69454
90	12	10.23	0.59614
91	12	9.25	0.68161
92	12	6.12	0.90981
93	12	6.48	0.89006
94	12	20.82	0.05303
95	12	20.35	0.06082
96	12	9.60	0.65081
97	12	20.34	0.06098
98	12	16.44	0.17189
99	12	6.22	0.90456
100	12	10.34	0.58642
Combined P-value for all tests (Using KS method)			0.48512

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	23.84	0.02140
2	12	17.87	0.11979
3	12	13.32	0.34591
4	12	6.28	0.90109
5	12	11.24	0.50872
6	12	13.14	0.35888
7	12	11.46	0.49012
8	12	4.05	0.98250
9	12	22.63	0.03100
10	12	9.45	0.66368
11	12	14.68	0.25945
12	12	8.84	0.71634
13	12	3.02	0.99541
14	12	8.47	0.74756
15	12	8.12	0.77580

16	12	3.84	0.98608
17	12	13.45	0.33700
18	12	8.63	0.73454
19	12	7.02	0.85652
20	12	13.54	0.33097
21	12	7.86	0.79597
22	12	18.08	0.11321
23	12	7.55	0.81938
24	12	7.78	0.80236
25	12	6.08	0.91182
26	12	8.63	0.73393
27	12	11.22	0.51006
28	12	11.05	0.52433
29	12	14.30	0.28183
30	12	9.75	0.63756
31	12	8.45	0.74922
32	12	6.53	0.88698
33	12	7.11	0.85053
34	12	6.34	0.89812
35	12	6.38	0.89568
36	12	3.10	0.99480
37	12	8.40	0.75348
38	12	16.36	0.17546
39	12	15.10	0.23580
40	12	12.36	0.41737
41	12	13.95	0.30402
42	12	23.04	0.02738
43	12	7.37	0.83241
44	12	18.00	0.11556
45	12	18.88	0.09137
46	12	4.96	0.95941
47	12	16.35	0.17558
48	12	9.94	0.62097
49	12	13.08	0.36344
50	12	5.24	0.94932
51	12	16.32	0.17695
52	12	10.27	0.59247
53	12	6.73	0.87490
54	12	17.95	0.11728
55	12	15.77	0.20180
56	12	16.49	0.16961
57	12	12.00	0.44581
58	12	9.99	0.61692
59	12	1.97	0.99945
60	12	10.98	0.53051
61	12	14.00	0.30096
62	12	11.88	0.45526
63	12	13.16	0.35723
64	12	17.43	0.13419
65	12	10.81	0.54493
66	12	17.38	0.13579
67	12	6.61	0.88242
68	12	16.97	0.15073
69	12	4.61	0.96975
70	12	14.45	0.27301

71	12	4.65	0.96865
72	12	7.69	0.80890
73	12	5.70	0.93037
74	12	11.47	0.48916
75	12	21.38	0.04509
76	12	18.69	0.09616
77	12	9.23	0.68357
78	12	11.83	0.45925
79	12	11.43	0.49282
80	12	10.73	0.55225
81	12	12.29	0.42263
82	12	16.48	0.17037
83	12	12.95	0.37237
84	12	9.13	0.69194
85	12	10.69	0.55557
86	12	9.74	0.63901
87	12	9.11	0.69347
88	12	14.66	0.26036
89	12	16.57	0.16635
90	12	4.49	0.97280
91	12	13.17	0.35706
92	12	3.52	0.99062
93	12	7.66	0.81081
94	12	6.75	0.87377
95	12	12.44	0.41114
96	12	16.28	0.17864
97	12	18.52	0.10084
98	12	16.32	0.17705
99	12	12.85	0.38032
100	12	20.69	0.05512
Combined P-value for all tests (Using KS method)			0.59416

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)	0.06828	0.34139
Opening Score (Dealer)	0.72724	1.00000
Dealer's Final Score	0.07546	0.34139
Player Cards Rank	0.48512	1.00000
Dealer Cards Rank	0.59416	1.00000
Combined P-Value using Holm's Method		0.34139

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.

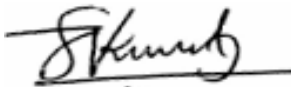
We conclude that the Random Number Generator (RNG) is working correctly.

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:



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iTech Labs Australia
Date: 01 August, 2022

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.