



Blackjack Cards Analysis – March 2021

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **March 01, 2021 to March 31, 2021** 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	18.50	0.35814
2	17	19.95	0.27666
3	17	23.46	0.13479
4	17	12.44	0.77294
5	17	16.02	0.52264
6	17	10.84	0.86457
7	17	17.47	0.42315
8	17	10.94	0.85961
9	17	8.29	0.96005
10	17	26.78	0.06138
11	17	22.87	0.15344
12	17	14.64	0.62118
13	17	18.16	0.37873
14	17	14.76	0.61283
15	17	14.86	0.60551
16	17	18.43	0.36217
17	17	22.34	0.17202
18	17	11.66	0.82030
19	17	10.92	0.86048
20	17	8.90	0.94322
21	17	12.86	0.74559
22	17	15.34	0.57066
23	17	25.53	0.08342

24	17	13.43	0.70676
25	17	14.43	0.63650
26	17	14.82	0.60838
27	17	17.17	0.44316
28	17	30.30	0.02428
29	17	13.72	0.68647
30	17	22.06	0.18223
31	17	15.03	0.59342
32	17	12.64	0.76023
33	17	9.07	0.93811
34	17	23.28	0.14021
35	17	11.17	0.84765
36	17	26.16	0.07168
37	17	35.42	0.00548
38	17	11.24	0.84405
39	17	18.31	0.36969
40	17	20.54	0.24764
41	17	19.62	0.29429
42	17	15.18	0.58223
43	17	24.12	0.11625
44	17	18.20	0.37627
45	17	16.77	0.46996
46	17	11.57	0.82520
47	17	17.32	0.43312
48	17	12.31	0.78107
49	17	15.87	0.53293
50	17	10.02	0.90285
51	17	9.70	0.91589
52	17	15.87	0.53310
53	17	18.96	0.33097
54	17	19.93	0.27769
55	17	17.55	0.41789
56	17	14.71	0.61621
57	17	24.52	0.10609
58	17	25.42	0.08577
59	17	13.94	0.67118
60	17	29.97	0.02653
61	17	8.52	0.95404
62	17	14.80	0.60974
63	17	10.40	0.88597
64	17	16.60	0.48201
65	17	5.97	0.99338
66	17	16.09	0.51742
67	17	15.04	0.59291
68	17	4.76	0.99838
69	17	24.35	0.11018
70	17	13.74	0.68530
71	17	26.83	0.06057
72	17	16.28	0.50443
73	17	13.72	0.68680
74	17	8.81	0.94598
75	17	27.57	0.05023
76	17	18.48	0.35926
77	17	11.03	0.85482
78	17	8.08	0.96477

79	17	15.61	0.55155
80	17	19.01	0.32774
81	17	9.87	0.90893
82	17	15.26	0.57670
83	17	17.68	0.40925
84	17	28.95	0.03501
85	17	15.45	0.56335
86	17	21.43	0.20755
87	17	24.02	0.11877
88	17	16.53	0.48678
89	17	18.21	0.37594
90	17	16.62	0.48026
91	17	15.89	0.53173
92	17	23.60	0.13062
93	17	13.55	0.69871
94	17	12.22	0.78667
95	17	21.60	0.20043
96	17	14.30	0.64553
97	17	11.84	0.80999
98	17	10.89	0.86201
99	17	14.98	0.59678
100	17	26.15	0.07176
Combined P-value for all tests (Using KS method)			0.72734

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	16.92	0.45948
2	17	14.56	0.62726
3	17	20.25	0.26141
4	17	15.16	0.58373
5	17	15.25	0.57756
6	17	10.86	0.86368
7	17	10.81	0.86621
8	17	24.86	0.09785
9	17	10.70	0.87188
10	17	21.63	0.19942
11	17	10.32	0.88945
12	17	10.98	0.85762
13	17	14.18	0.65409
14	17	16.86	0.46416
15	17	9.33	0.92950
16	17	10.65	0.87404
17	17	18.05	0.38559
18	17	22.92	0.15198
19	17	12.78	0.75081
20	17	10.29	0.89099
21	17	9.20	0.93381
22	17	7.54	0.97546
23	17	10.19	0.89540

24	17	16.63	0.47984
25	17	7.99	0.96685
26	17	25.10	0.09253
27	17	19.41	0.30572
28	17	21.46	0.20639
29	17	19.05	0.32572
30	17	21.24	0.21590
31	17	29.98	0.02649
32	17	17.63	0.41264
33	17	20.28	0.26013
34	17	17.26	0.43677
35	17	13.45	0.70554
36	17	25.53	0.08356
37	17	15.38	0.56838
38	17	15.74	0.54258
39	17	27.59	0.05002
40	17	9.83	0.91060
41	17	18.10	0.38246
42	17	20.42	0.25313
43	17	16.77	0.46988
44	17	25.69	0.08031
45	17	9.41	0.92661
46	17	15.26	0.57690
47	17	15.87	0.53275
48	17	10.56	0.87851
49	17	17.05	0.45126
50	17	23.01	0.14889
51	17	12.72	0.75498
52	17	26.77	0.06156
53	17	20.15	0.26676
54	17	22.27	0.17457
55	17	16.93	0.45891
56	17	34.06	0.00826
57	17	13.58	0.69691
58	17	18.84	0.33787
59	17	17.46	0.42371
60	17	21.40	0.20887
61	17	16.16	0.51222
62	17	12.32	0.78054
63	17	18.74	0.34339
64	17	17.24	0.43847
65	17	15.67	0.54720
66	17	30.64	0.02210
67	17	23.67	0.12854
68	17	15.24	0.57837
69	17	11.89	0.80701
70	17	15.12	0.58660
71	17	13.82	0.68003
72	17	17.05	0.45130
73	17	23.87	0.12294
74	17	11.61	0.82307
75	17	24.38	0.10950
76	17	26.12	0.07225
77	17	18.61	0.35133
78	17	15.34	0.57081

79	17	19.16	0.31945
80	17	10.14	0.89768
81	17	18.45	0.36104
82	17	18.74	0.34338
83	17	16.49	0.48961
84	17	11.48	0.83061
85	17	18.32	0.36905
86	17	30.91	0.02050
87	17	17.40	0.42787
88	17	17.16	0.44357
89	17	12.82	0.74805
90	17	13.89	0.67460
91	17	21.58	0.20142
92	17	18.27	0.37178
93	17	30.85	0.02081
94	17	31.56	0.01704
95	17	8.36	0.95833
96	17	16.25	0.50600
97	17	27.61	0.04971
98	17	19.30	0.31163
99	17	9.97	0.90498
100	17	15.78	0.53941
Combined P-value for all tests (Using KS method)			0.33213

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	52.78	0.36726
2	50	57.94	0.20560
3	50	41.37	0.80252
4	50	46.84	0.60091
5	50	62.78	0.10589
6	50	49.73	0.48408
7	50	58.91	0.18178
8	50	38.49	0.88210
9	50	47.13	0.58924
10	50	57.79	0.20973
11	50	67.16	0.05301
12	50	60.22	0.15256
13	50	39.42	0.85883
14	50	52.14	0.39057
15	50	60.11	0.15501
16	50	53.52	0.34090
17	50	68.76	0.04029
18	50	51.67	0.40845
19	50	49.72	0.48473
20	50	38.77	0.87538
21	50	67.27	0.05203
22	50	53.16	0.35358
23	50	42.74	0.75723

24	50	74.64	0.01353
25	50	55.96	0.26114
26	50	48.27	0.54320
27	50	57.65	0.21339
28	50	83.85	0.00191
29	50	42.17	0.77640
30	50	47.15	0.58832
31	50	62.25	0.11461
32	50	43.05	0.74613
33	50	54.24	0.31590
34	50	37.40	0.90608
35	50	64.88	0.07683
36	50	56.42	0.24757
37	50	57.02	0.23043
38	50	49.81	0.48093
39	50	62.09	0.11723
40	50	39.03	0.86892
41	50	31.98	0.97786
42	50	40.53	0.82809
43	50	41.49	0.79869
44	50	44.10	0.70796
45	50	61.52	0.12730
46	50	41.57	0.79604
47	50	60.40	0.14898
48	50	51.24	0.42470
49	50	46.73	0.60534
50	50	50.27	0.46251
51	50	37.80	0.89752
52	50	70.04	0.03215
53	50	52.70	0.37002
54	50	60.56	0.14567
55	50	54.01	0.32374
56	50	57.81	0.20896
57	50	53.72	0.33373
58	50	41.42	0.80108
59	50	57.31	0.22246
60	50	34.25	0.95643
61	50	61.69	0.12428
62	50	45.72	0.64551
63	50	48.49	0.53405
64	50	58.53	0.19084
65	50	50.98	0.43491
66	50	50.56	0.45146
67	50	52.94	0.36145
68	50	52.82	0.36576
69	50	46.71	0.60602
70	50	39.06	0.86812
71	50	49.57	0.49054
72	50	62.40	0.11208
73	50	66.31	0.06097
74	50	79.51	0.00498
75	50	53.89	0.32789
76	50	54.26	0.31540
77	50	40.30	0.83475
78	50	56.12	0.25618

79	50	61.67	0.12458
80	50	50.40	0.45751
81	50	47.67	0.56726
82	50	65.17	0.07333
83	50	36.62	0.92108
84	50	54.05	0.32242
85	50	62.07	0.11765
86	50	55.68	0.26969
87	50	60.09	0.15525
88	50	54.88	0.29501
89	50	47.68	0.56695
90	50	42.24	0.77417
91	50	57.29	0.22307
92	50	49.82	0.48074
93	50	47.63	0.56913
94	50	54.64	0.30261
95	50	47.40	0.57852
96	50	61.44	0.12878
97	50	57.27	0.22362
98	50	55.07	0.28886
99	50	42.47	0.76652
100	50	57.94	0.20582
Combined P-value for all tests			0.01046

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	17.04	0.14800
2	12	9.51	0.65875
3	12	25.52	0.01255
4	12	7.98	0.78645
5	12	12.17	0.43174
6	12	12.18	0.43151
7	12	5.71	0.92988
8	12	6.47	0.89043
9	12	12.95	0.37275
10	12	16.91	0.15302
11	12	12.80	0.38404
12	12	10.55	0.56796
13	12	12.60	0.39859
14	12	12.74	0.38857
15	12	10.66	0.55866

16	12	12.30	0.42197
17	12	14.88	0.24797
18	12	23.76	0.02195
19	12	5.30	0.94734
20	12	15.78	0.20151
21	12	12.28	0.42378
22	12	18.31	0.10649
23	12	9.97	0.61853
24	12	7.14	0.84845
25	12	14.50	0.26973
26	12	14.56	0.26649
27	12	16.00	0.19138
28	12	19.06	0.08704
29	12	10.34	0.58637
30	12	15.00	0.24142
31	12	13.66	0.32296
32	12	15.57	0.21162
33	12	9.98	0.61752
34	12	10.12	0.60510
35	12	23.77	0.02187
36	12	25.72	0.01176
37	12	10.25	0.59447
38	12	10.59	0.56469
39	12	16.63	0.16395
40	12	3.81	0.98656
41	12	12.69	0.39160
42	12	6.71	0.87604
43	12	15.31	0.22510
44	12	10.04	0.61220
45	12	9.80	0.63374
46	12	15.93	0.19444
47	12	7.87	0.79517
48	12	5.46	0.94070
49	12	11.40	0.49530
50	12	7.11	0.85052
51	12	6.76	0.87287
52	12	10.88	0.53911
53	12	14.86	0.24907
54	12	10.95	0.53307
55	12	15.82	0.19968
56	12	22.38	0.03346
57	12	15.55	0.21281
58	12	12.04	0.44218
59	12	24.23	0.01891
60	12	17.70	0.12524
61	12	12.31	0.42101
62	12	15.54	0.21332
63	12	8.94	0.70811
64	12	9.06	0.69768
65	12	5.82	0.92504
66	12	8.16	0.77236
67	12	11.95	0.44949
68	12	16.79	0.15752
69	12	6.30	0.90020
70	12	5.80	0.92602

71	12	16.92	0.15278
72	12	10.68	0.55642
73	12	14.37	0.27799
74	12	4.94	0.95986
75	12	11.72	0.46854
76	12	13.83	0.31154
77	12	11.46	0.49030
78	12	7.97	0.78752
79	12	11.13	0.51817
80	12	10.25	0.59362
81	12	6.41	0.89376
82	12	7.08	0.85244
83	12	14.49	0.27051
84	12	7.51	0.82184
85	12	11.77	0.46470
86	12	10.11	0.60615
87	12	9.86	0.62805
88	12	9.82	0.63192
89	12	6.72	0.87530
90	12	7.38	0.83157
91	12	22.53	0.03200
92	12	18.82	0.09286
93	12	21.51	0.04342
94	12	9.29	0.67796
95	12	5.82	0.92504
96	12	4.50	0.97268
97	12	14.01	0.29996
98	12	15.84	0.19869
99	12	13.69	0.32081
100	12	19.54	0.07627
Combined P-value for all tests (Using KS method)			0.58923

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	10.48	0.57358
2	12	9.36	0.67191
3	12	11.08	0.52173
4	12	9.80	0.63333
5	12	12.21	0.42912
6	12	6.12	0.90991
7	12	16.84	0.15564
8	12	4.59	0.97019
9	12	14.63	0.26241
10	12	6.63	0.88131
11	12	11.94	0.45083
12	12	14.01	0.29994
13	12	12.85	0.37989
14	12	3.61	0.98949
15	12	8.02	0.78372

16	12	11.68	0.47138
17	12	12.18	0.43118
18	12	10.47	0.57497
19	12	7.86	0.79567
20	12	12.78	0.38538
21	12	8.96	0.70600
22	12	10.43	0.57829
23	12	14.68	0.25929
24	12	6.83	0.86851
25	12	8.58	0.73799
26	12	13.59	0.32765
27	12	12.55	0.40227
28	12	9.91	0.62421
29	12	17.16	0.14375
30	12	9.12	0.69230
31	12	13.02	0.36744
32	12	7.97	0.78747
33	12	11.49	0.48779
34	12	12.20	0.43007
35	12	10.70	0.55444
36	12	8.01	0.78419
37	12	13.95	0.30378
38	12	18.00	0.11569
39	12	19.70	0.07290
40	12	7.83	0.79812
41	12	19.40	0.07941
42	12	16.73	0.16004
43	12	13.51	0.33295
44	12	33.67	0.00076
45	12	7.71	0.80766
46	12	15.54	0.21342
47	12	8.40	0.75314
48	12	15.64	0.20819
49	12	7.85	0.79659
50	12	11.29	0.50391
51	12	16.04	0.18932
52	12	6.68	0.87814
53	12	16.54	0.16790
54	12	14.21	0.28775
55	12	3.75	0.98760
56	12	8.81	0.71941
57	12	7.74	0.80526
58	12	14.36	0.27807
59	12	12.20	0.43007
60	12	10.10	0.60719
61	12	12.84	0.38092
62	12	9.00	0.70276
63	12	5.99	0.91638
64	12	6.67	0.87887
65	12	10.64	0.55982
66	12	5.32	0.94627
67	12	17.06	0.14721
68	12	3.76	0.98745
69	12	8.75	0.72395
70	12	7.11	0.85038

71	12	25.25	0.01369
72	12	8.16	0.77271
73	12	21.15	0.04825
74	12	9.44	0.66474
75	12	11.33	0.50107
76	12	21.94	0.03825
77	12	11.61	0.47735
78	12	9.53	0.65713
79	12	10.53	0.56917
80	12	11.29	0.50389
81	12	14.56	0.26612
82	12	18.49	0.10174
83	12	14.12	0.29318
84	12	6.69	0.87727
85	12	15.22	0.22972
86	12	11.52	0.48474
87	12	5.40	0.94336
88	12	4.19	0.97979
89	12	14.98	0.24250
90	12	16.26	0.17961
91	12	7.64	0.81292
92	12	14.10	0.29423
93	12	23.13	0.02666
94	12	13.98	0.30225
95	12	9.52	0.65794
96	12	14.02	0.29964
97	12	7.99	0.78574
98	12	13.02	0.36776
99	12	16.80	0.15711
100	12	8.32	0.75929
Combined P-value for all tests (Using KS method)			0.92819

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)	0.72734	1.00000
Opening Score (Dealer)	0.33213	1.00000
Dealer's Final Score	0.01046	0.05228
Player Cards Rank	0.58923	1.00000
Dealer Cards Rank	0.92819	1.00000
Combined P-Value using Holm's Method		0.05228

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.

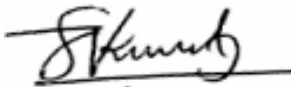
We conclude that the Random Number Generator (RNG) is working correctly.

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: 03 June, 2021

Signed:



Gyulserian Hyussein
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Date: 03 June, 2021

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.