



Blackjack Cards Analysis – July 2022

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **July 01, 2022 to July 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	10.05	0.90136
2	17	25.65	0.08117
3	17	22.86	0.15381
4	17	15.09	0.58875
5	17	10.88	0.86278
6	17	23.46	0.13490
7	17	19.87	0.28077
8	17	22.65	0.16109
9	17	26.67	0.06312
10	17	12.46	0.77141
11	17	13.29	0.71644
12	17	17.49	0.42153
13	17	9.59	0.91978
14	17	24.90	0.09691
15	17	9.45	0.92508
16	17	28.86	0.03588
17	17	11.52	0.82801
18	17	27.15	0.05590
19	17	17.13	0.44573
20	17	13.02	0.73483
21	17	17.87	0.39706
22	17	31.91	0.01546
23	17	15.02	0.59376

24	17	14.40	0.63879
25	17	18.90	0.33425
26	17	25.04	0.09387
27	17	21.79	0.19296
28	17	17.76	0.40434
29	17	26.03	0.07385
30	17	25.75	0.07917
31	17	6.68	0.98731
32	17	15.58	0.55383
33	17	18.48	0.35946
34	17	16.62	0.48055
35	17	7.89	0.96878
36	17	33.90	0.00866
37	17	24.78	0.09982
38	17	25.30	0.08820
39	17	8.12	0.96399
40	17	18.40	0.36386
41	17	9.83	0.91076
42	17	14.87	0.60496
43	17	16.05	0.52058
44	17	14.17	0.65506
45	17	33.80	0.00892
46	17	14.19	0.65386
47	17	9.07	0.93798
48	17	14.09	0.66091
49	17	18.98	0.32940
50	17	10.74	0.86987
51	17	13.15	0.72591
52	17	6.19	0.99184
53	17	24.79	0.09941
54	17	13.78	0.68290
55	17	16.58	0.48282
56	17	9.01	0.94008
57	17	19.87	0.28082
58	17	19.55	0.29791
59	17	13.91	0.67381
60	17	10.40	0.88617
61	17	17.80	0.40147
62	17	19.37	0.30761
63	17	17.99	0.38951
64	17	18.38	0.36499
65	17	15.76	0.54082
66	17	13.88	0.67588
67	17	13.01	0.73574
68	17	14.21	0.65218
69	17	22.23	0.17593
70	17	18.80	0.34035
71	17	32.72	0.01224
72	17	13.85	0.67795
73	17	29.39	0.03112
74	17	12.57	0.76414
75	17	21.39	0.20945
76	17	19.00	0.32843
77	17	23.65	0.12934
78	17	5.50	0.99598

79	17	32.60	0.01266
80	17	11.67	0.81997
81	17	14.73	0.61525
82	17	6.86	0.98529
83	17	17.59	0.41541
84	17	24.11	0.11640
85	17	12.68	0.75735
86	17	9.75	0.91359
87	17	14.98	0.59660
88	17	14.60	0.62437
89	17	11.35	0.83760
90	17	39.58	0.00148
91	17	15.01	0.59444
92	17	24.85	0.09817
93	17	19.07	0.32470
94	17	11.08	0.85216
95	17	13.00	0.73605
96	17	24.29	0.11166
97	17	17.02	0.45331
98	17	21.62	0.19987
99	17	12.08	0.79557
100	17	9.95	0.90550
Combined P-value for all tests (Using KS method)			0.44700

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	13.01	0.73570
2	17	21.80	0.19252
3	17	33.28	0.01040
4	17	18.66	0.34866
5	17	10.09	0.89968
6	17	27.91	0.04595
7	17	35.12	0.00599
8	17	24.76	0.10012
9	17	17.28	0.43579
10	17	11.41	0.83470
11	17	28.27	0.04186
12	17	11.61	0.82294
13	17	11.38	0.83622
14	17	9.51	0.92276
15	17	16.41	0.49482
16	17	17.57	0.41661
17	17	16.85	0.46438
18	17	27.18	0.05546
19	17	20.81	0.23509
20	17	17.72	0.40674
21	17	13.82	0.68012
22	17	6.73	0.98678
23	17	10.62	0.87573

24	17	7.44	0.97705
25	17	8.39	0.95740
26	17	21.40	0.20890
27	17	13.35	0.71277
28	17	30.59	0.02239
29	17	20.31	0.25892
30	17	20.87	0.23232
31	17	23.37	0.13745
32	17	18.04	0.38621
33	17	17.66	0.41059
34	17	10.54	0.87965
35	17	6.79	0.98606
36	17	10.32	0.88974
37	17	22.42	0.16918
38	17	20.39	0.25472
39	17	24.86	0.09782
40	17	13.09	0.73024
41	17	20.09	0.26987
42	17	16.84	0.46551
43	17	26.62	0.06390
44	17	16.27	0.50467
45	17	20.63	0.24328
46	17	14.67	0.61910
47	17	11.10	0.85157
48	17	7.56	0.97512
49	17	17.51	0.42031
50	17	12.05	0.79739
51	17	12.97	0.73821
52	17	35.23	0.00579
53	17	18.86	0.33660
54	17	10.59	0.87707
55	17	18.53	0.35625
56	17	18.41	0.36355
57	17	9.92	0.90709
58	17	21.61	0.20019
59	17	14.33	0.64375
60	17	11.10	0.85157
61	17	15.05	0.59187
62	17	17.01	0.45383
63	17	9.50	0.92335
64	17	9.95	0.90554
65	17	8.51	0.95445
66	17	26.63	0.06379
67	17	12.06	0.79677
68	17	12.54	0.76657
69	17	16.12	0.51505
70	17	20.78	0.23624
71	17	18.70	0.34592
72	17	9.58	0.92012
73	17	9.30	0.93048
74	17	11.01	0.85607
75	17	10.15	0.89716
76	17	26.09	0.07286
77	17	22.58	0.16329
78	17	11.48	0.83082

79	17	14.09	0.66061
80	17	12.96	0.73873
81	17	19.86	0.28157
82	17	8.48	0.95526
83	17	15.92	0.52978
84	17	16.56	0.48468
85	17	14.38	0.64019
86	17	9.87	0.90903
87	17	27.31	0.05369
88	17	14.29	0.64656
89	17	15.07	0.59011
90	17	15.81	0.53719
91	17	18.54	0.35552
92	17	13.48	0.70355
93	17	13.21	0.72181
94	17	20.62	0.24388
95	17	11.86	0.80860
96	17	12.67	0.75789
97	17	16.28	0.50393
98	17	20.78	0.23635
99	17	10.55	0.87917
100	17	9.00	0.94035
Combined P-value for all tests (Using KS method)			0.12174

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	34.72	0.95053
2	50	45.56	0.65211
3	50	31.87	0.97860
4	50	72.22	0.02154
5	50	64.71	0.07890
6	50	45.76	0.64412
7	50	49.12	0.50853
8	50	49.06	0.51100
9	50	60.98	0.13734
10	50	51.32	0.42183
11	50	45.45	0.65620
12	50	53.83	0.33010
13	50	50.77	0.44313
14	50	51.69	0.40776
15	50	48.75	0.52379
16	50	51.41	0.41831
17	50	51.17	0.42748
18	50	55.14	0.28645
19	50	43.00	0.74791
20	50	48.98	0.51412
21	50	64.46	0.08209
22	50	45.66	0.64814
23	50	59.51	0.16790

24	50	53.43	0.34400
25	50	34.37	0.95497
26	50	54.91	0.29394
27	50	44.06	0.70944
28	50	42.49	0.76562
29	50	50.77	0.44306
30	50	42.82	0.75433
31	50	52.86	0.36416
32	50	48.18	0.54650
33	50	49.48	0.49403
34	50	46.04	0.63284
35	50	32.35	0.97507
36	50	42.83	0.75391
37	50	56.19	0.25414
38	50	68.56	0.04170
39	50	57.65	0.21340
40	50	41.05	0.81231
41	50	50.78	0.44281
42	50	53.41	0.34465
43	50	46.79	0.60290
44	50	45.51	0.65410
45	50	60.57	0.14539
46	50	49.03	0.51226
47	50	51.19	0.42685
48	50	72.07	0.02215
49	50	39.20	0.86451
50	50	50.22	0.46455
51	50	74.07	0.01511
52	50	33.83	0.96122
53	50	48.67	0.52679
54	50	41.66	0.79314
55	50	36.29	0.92683
56	50	65.28	0.07213
57	50	61.08	0.13551
58	50	48.83	0.52039
59	50	45.56	0.65180
60	50	52.36	0.38253
61	50	44.09	0.70853
62	50	59.51	0.16802
63	50	46.91	0.59806
64	50	55.47	0.27605
65	50	41.55	0.79683
66	50	54.25	0.31562
67	50	69.72	0.03403
68	50	33.02	0.96934
69	50	62.13	0.11662
70	50	65.90	0.06524
71	50	56.94	0.23248
72	50	51.03	0.43310
73	50	43.63	0.72533
74	50	41.51	0.79821
75	50	42.67	0.75950
76	50	47.48	0.57507
77	50	55.15	0.28608
78	50	45.87	0.63980

79	50	62.89	0.10429
80	50	43.48	0.73078
81	50	40.60	0.82594
82	50	50.97	0.43536
83	50	77.38	0.00778
84	50	31.20	0.98289
85	50	64.42	0.08251
86	50	38.37	0.88490
87	50	47.85	0.56012
88	50	57.89	0.20703
89	50	44.19	0.70474
90	50	43.78	0.71992
91	50	52.54	0.37579
92	50	50.67	0.44690
93	50	30.54	0.98639
94	50	54.30	0.31391
95	50	49.35	0.49927
96	50	65.30	0.07188
97	50	51.38	0.41952
98	50	56.70	0.23950
99	50	46.23	0.62543
100	50	45.94	0.63704
Combined P-value for all tests			0.78853

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	14.44	0.27352
2	12	23.88	0.02115
3	12	16.23	0.18101
4	12	13.81	0.31292
5	12	7.79	0.80148
6	12	12.56	0.40190
7	12	9.31	0.67644
8	12	7.38	0.83163
9	12	10.04	0.61215
10	12	18.27	0.10779
11	12	10.75	0.55029
12	12	13.48	0.33508
13	12	6.64	0.88075
14	12	23.45	0.02412
15	12	5.54	0.93748

16	12	23.02	0.02756
17	12	8.43	0.75093
18	12	10.27	0.59192
19	12	12.71	0.39042
20	12	16.22	0.18148
21	12	16.99	0.14986
22	12	12.23	0.42776
23	12	5.08	0.95512
24	12	13.50	0.33404
25	12	7.37	0.83255
26	12	10.02	0.61396
27	12	11.20	0.51229
28	12	7.08	0.85232
29	12	9.04	0.69930
30	12	13.22	0.35358
31	12	3.02	0.99538
32	12	10.58	0.56562
33	12	8.56	0.73995
34	12	9.85	0.62888
35	12	10.63	0.56100
36	12	14.14	0.29175
37	12	15.89	0.19647
38	12	12.56	0.40182
39	12	8.55	0.74076
40	12	7.09	0.85174
41	12	9.28	0.67906
42	12	13.40	0.34090
43	12	15.30	0.22528
44	12	13.25	0.35113
45	12	16.77	0.15863
46	12	10.63	0.56110
47	12	14.57	0.26601
48	12	8.52	0.74327
49	12	17.61	0.12815
50	12	7.01	0.85695
51	12	12.50	0.40679
52	12	8.41	0.75250
53	12	12.99	0.36969
54	12	9.19	0.68636
55	12	11.06	0.52406
56	12	9.45	0.66410
57	12	12.88	0.37760
58	12	12.41	0.41344
59	12	13.12	0.36037
60	12	7.28	0.83854
61	12	9.29	0.67809
62	12	15.04	0.23903
63	12	13.94	0.30472
64	12	4.22	0.97909
65	12	5.31	0.94671
66	12	5.26	0.94885
67	12	15.31	0.22512
68	12	5.51	0.93873
69	12	21.50	0.04358
70	12	19.23	0.08313

71	12	11.94	0.45079
72	12	14.78	0.25352
73	12	6.73	0.87517
74	12	8.74	0.72517
75	12	12.27	0.42430
76	12	10.81	0.54543
77	12	4.84	0.96315
78	12	13.15	0.35822
79	12	12.78	0.38539
80	12	22.91	0.02852
81	12	9.73	0.63966
82	12	10.34	0.58642
83	12	9.66	0.64603
84	12	11.11	0.51971
85	12	16.93	0.15238
86	12	8.48	0.74679
87	12	12.46	0.40942
88	12	12.98	0.37044
89	12	14.74	0.25588
90	12	11.63	0.47560
91	12	8.74	0.72500
92	12	8.15	0.77322
93	12	6.03	0.91449
94	12	7.69	0.80869
95	12	7.75	0.80431
96	12	15.87	0.19737
97	12	16.32	0.17687
98	12	7.90	0.79271
99	12	7.64	0.81272
100	12	13.12	0.36023
Combined P-value for all tests (Using KS method)			0.62696

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	14.27	0.28362
2	12	5.10	0.95441
3	12	8.77	0.72224
4	12	14.70	0.25828
5	12	8.62	0.73524
6	12	13.96	0.30336
7	12	12.31	0.42148
8	12	8.33	0.75844
9	12	10.00	0.61585
10	12	13.02	0.36773
11	12	24.90	0.01532
12	12	12.02	0.44370
13	12	5.34	0.94581
14	12	9.63	0.64822
15	12	14.79	0.25309

16	12	12.93	0.37398
17	12	8.20	0.76916
18	12	15.74	0.20364
19	12	7.95	0.78888
20	12	8.48	0.74663
21	12	6.42	0.89370
22	12	14.03	0.29896
23	12	17.82	0.12126
24	12	15.23	0.22924
25	12	12.99	0.37007
26	12	10.03	0.61290
27	12	14.84	0.25012
28	12	14.77	0.25439
29	12	14.80	0.25270
30	12	16.77	0.15829
31	12	8.49	0.74600
32	12	19.73	0.07243
33	12	10.07	0.60961
34	12	14.26	0.28466
35	12	12.30	0.42202
36	12	11.17	0.51450
37	12	15.91	0.19557
38	12	18.22	0.10912
39	12	7.44	0.82687
40	12	14.57	0.26578
41	12	14.69	0.25903
42	12	11.06	0.52421
43	12	15.62	0.20914
44	12	8.53	0.74253
45	12	8.27	0.76363
46	12	12.23	0.42772
47	12	11.79	0.46232
48	12	5.82	0.92496
49	12	14.10	0.29422
50	12	13.40	0.34041
51	12	13.72	0.31889
52	12	16.22	0.18141
53	12	7.24	0.84136
54	12	6.34	0.89791
55	12	5.13	0.95360
56	12	12.27	0.42430
57	12	11.45	0.49058
58	12	6.63	0.88123
59	12	16.79	0.15751
60	12	17.71	0.12488
61	12	6.73	0.87484
62	12	12.44	0.41121
63	12	5.68	0.93115
64	12	9.68	0.64407
65	12	8.53	0.74241
66	12	13.96	0.30312
67	12	17.13	0.14478
68	12	5.09	0.95484
69	12	11.48	0.48834
70	12	7.96	0.78829

71	12	9.66	0.64534
72	12	17.05	0.14780
73	12	8.01	0.78423
74	12	12.34	0.41886
75	12	13.24	0.35213
76	12	12.94	0.37347
77	12	9.24	0.68214
78	12	17.70	0.12510
79	12	19.74	0.07217
80	12	8.98	0.70428
81	12	10.43	0.57861
82	12	15.89	0.19621
83	12	5.44	0.94173
84	12	15.51	0.21448
85	12	33.91	0.00070
86	12	13.67	0.32205
87	12	16.25	0.18020
88	12	7.69	0.80867
89	12	11.40	0.49478
90	12	4.73	0.96637
91	12	8.42	0.75183
92	12	9.76	0.63714
93	12	13.30	0.34738
94	12	19.43	0.07870
95	12	12.77	0.38609
96	12	17.79	0.12238
97	12	6.48	0.88975
98	12	8.19	0.77009
99	12	11.78	0.46328
100	12	10.30	0.58958
Combined P-value for all tests (Using KS method)			0.65711

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)	0.44700	1.00000
Opening Score (Dealer)	0.12174	0.60868
Dealer's Final Score	0.78853	1.00000
Player Cards Rank	0.62696	1.00000
Dealer Cards Rank	0.65711	1.00000
Combined P-Value using Holm's Method		0.60868

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.

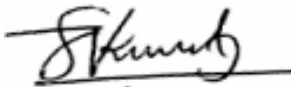
We conclude that the Random Number Generator (RNG) is working correctly.

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: 19 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.