



Blackjack Cards Analysis – December 2021

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **December 01, 2021 to December 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	19.90	0.27928
2	17	9.58	0.92044
3	17	33.61	0.00942
4	17	18.05	0.38596
5	17	19.02	0.32720
6	17	8.30	0.95975
7	17	15.88	0.53209
8	17	17.32	0.43261
9	17	23.14	0.14473
10	17	17.31	0.43335
11	17	14.46	0.63452
12	17	8.30	0.95959
13	17	9.90	0.90768
14	17	21.68	0.19738
15	17	17.56	0.41737
16	17	18.78	0.34154
17	17	4.77	0.99834
18	17	28.33	0.04126
19	17	11.62	0.82264
20	17	15.55	0.55602
21	17	28.72	0.03720
22	17	22.67	0.16035
23	17	16.06	0.51987

24	17	17.58	0.41603
25	17	14.79	0.61027
26	17	17.85	0.39810
27	17	15.66	0.54787
28	17	16.50	0.48900
29	17	5.76	0.99464
30	17	14.27	0.64774
31	17	17.99	0.38928
32	17	17.03	0.45215
33	17	14.39	0.63935
34	17	12.54	0.76623
35	17	21.77	0.19374
36	17	10.86	0.86359
37	17	8.20	0.96217
38	17	15.94	0.52774
39	17	28.24	0.04224
40	17	17.55	0.41798
41	17	10.96	0.85861
42	17	18.92	0.33341
43	17	13.93	0.67187
44	17	18.15	0.37944
45	17	9.53	0.92218
46	17	27.95	0.04551
47	17	27.74	0.04805
48	17	9.55	0.92142
49	17	24.20	0.11411
50	17	16.04	0.52121
51	17	24.41	0.10872
52	17	8.51	0.95443
53	17	12.83	0.74772
54	17	9.88	0.90864
55	17	17.21	0.43991
56	17	16.15	0.51306
57	17	13.55	0.69853
58	17	9.09	0.93755
59	17	13.14	0.72652
60	17	11.02	0.85560
61	17	21.36	0.21042
62	17	32.55	0.01286
63	17	20.85	0.23309
64	17	20.61	0.24418
65	17	21.73	0.19517
66	17	16.10	0.51675
67	17	33.81	0.00888
68	17	14.60	0.62413
69	17	26.88	0.05992
70	17	25.33	0.08752
71	17	20.01	0.27367
72	17	20.37	0.25564
73	17	13.23	0.72095
74	17	12.75	0.75301
75	17	21.86	0.19014
76	17	7.56	0.97501
77	17	8.47	0.95531
78	17	19.19	0.31798

79	17	20.91	0.23043
80	17	21.23	0.21615
81	17	11.48	0.83035
82	17	11.41	0.83457
83	17	5.79	0.99451
84	17	10.69	0.87231
85	17	16.28	0.50428
86	17	22.04	0.18307
87	17	14.19	0.65340
88	17	16.42	0.49430
89	17	25.86	0.07699
90	17	15.45	0.56303
91	17	18.28	0.37113
92	17	20.79	0.23567
93	17	10.15	0.89728
94	17	24.63	0.10335
95	17	11.63	0.82206
96	17	31.46	0.01754
97	17	30.28	0.02437
98	17	7.97	0.96713
99	17	19.43	0.30426
100	17	30.56	0.02255
Combined P-value for all tests (Using KS method)			0.66090

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	11.76	0.81426
2	17	21.52	0.20385
3	17	11.31	0.83985
4	17	18.86	0.33647
5	17	15.75	0.54167
6	17	22.44	0.16838
7	17	24.66	0.10253
8	17	22.73	0.15830
9	17	16.77	0.46992
10	17	14.72	0.61551
11	17	24.29	0.11187
12	17	7.25	0.98012
13	17	19.09	0.32330
14	17	20.37	0.25585
15	17	12.40	0.77536
16	17	18.13	0.38075
17	17	17.12	0.44615
18	17	14.69	0.61771
19	17	23.43	0.13583
20	17	16.78	0.46912
21	17	20.77	0.23672
22	17	18.27	0.37171
23	17	19.27	0.31299

24	17	28.75	0.03694
25	17	16.26	0.50549
26	17	21.18	0.21823
27	17	11.33	0.83882
28	17	12.52	0.76783
29	17	14.84	0.60693
30	17	16.96	0.45694
31	17	22.31	0.17299
32	17	14.08	0.66142
33	17	26.53	0.06540
34	17	23.44	0.13543
35	17	22.69	0.15953
36	17	23.82	0.12449
37	17	12.98	0.73747
38	17	14.59	0.62490
39	17	17.09	0.44837
40	17	20.84	0.23361
41	17	7.85	0.96963
42	17	16.73	0.47249
43	17	10.47	0.88292
44	17	13.28	0.71706
45	17	22.88	0.15311
46	17	16.57	0.48371
47	17	12.93	0.74066
48	17	21.40	0.20905
49	17	27.15	0.05592
50	17	24.12	0.11633
51	17	14.08	0.66117
52	17	25.27	0.08893
53	17	20.82	0.23464
54	17	13.96	0.66990
55	17	20.07	0.27059
56	17	11.22	0.84482
57	17	24.90	0.09688
58	17	16.86	0.46358
59	17	22.39	0.17020
60	17	18.49	0.35848
61	17	10.38	0.88673
62	17	13.08	0.73091
63	17	13.89	0.67495
64	17	18.48	0.35927
65	17	18.96	0.33064
66	17	16.68	0.47644
67	17	13.80	0.68125
68	17	12.15	0.79123
69	17	15.88	0.53236
70	17	17.04	0.45165
71	17	13.74	0.68509
72	17	15.28	0.57497
73	17	15.42	0.56552
74	17	18.61	0.35156
75	17	24.79	0.09956
76	17	11.61	0.82331
77	17	26.46	0.06643
78	17	13.85	0.67771

79	17	5.06	0.99760
80	17	23.34	0.13838
81	17	13.43	0.70696
82	17	26.92	0.05926
83	17	33.55	0.00960
84	17	22.16	0.17854
85	17	17.76	0.40437
86	17	15.57	0.55445
87	17	16.14	0.51365
88	17	24.50	0.10655
89	17	20.99	0.22666
90	17	25.82	0.07777
91	17	10.08	0.90037
92	17	13.94	0.67134
93	17	18.64	0.34937
94	17	8.51	0.95452
95	17	8.88	0.94402
96	17	26.71	0.06251
97	17	18.65	0.34895
98	17	26.90	0.05949
99	17	17.39	0.42813
100	17	19.05	0.32582
Combined P-value for all tests (Using KS method)			0.19657

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	70.19	0.03127
2	50	37.07	0.91253
3	50	51.94	0.39836
4	50	48.88	0.51814
5	50	75.74	0.01087
6	50	56.51	0.24475
7	50	50.61	0.44944
8	50	61.00	0.13708
9	50	53.97	0.32532
10	50	36.09	0.93027
11	50	40.16	0.83871
12	50	47.88	0.55877
13	50	46.16	0.62803
14	50	45.94	0.63716
15	50	59.68	0.16425
16	50	44.15	0.70610
17	50	43.28	0.73817
18	50	50.05	0.47157
19	50	54.12	0.32017
20	50	39.72	0.85104
21	50	50.06	0.47103
22	50	41.46	0.79978
23	50	34.55	0.95274

24	50	58.90	0.18188
25	50	57.22	0.22492
26	50	45.87	0.63975
27	50	40.72	0.82243
28	50	59.90	0.15941
29	50	45.74	0.64502
30	50	63.37	0.09693
31	50	85.55	0.00130
32	50	55.26	0.28282
33	50	42.38	0.76950
34	50	53.01	0.35875
35	50	36.44	0.92430
36	50	39.22	0.86405
37	50	64.97	0.07569
38	50	37.52	0.90359
39	50	32.68	0.97238
40	50	40.61	0.82574
41	50	58.64	0.18826
42	50	44.17	0.70540
43	50	37.97	0.89383
44	50	55.91	0.26258
45	50	58.01	0.20379
46	50	41.90	0.78543
47	50	51.86	0.40107
48	50	63.71	0.09204
49	50	53.97	0.32509
50	50	55.99	0.26006
51	50	50.35	0.45942
52	50	36.24	0.92776
53	50	37.58	0.90236
54	50	55.52	0.27469
55	50	47.47	0.57563
56	50	55.46	0.27652
57	50	43.36	0.73514
58	50	51.36	0.42029
59	50	52.05	0.39416
60	50	43.46	0.73140
61	50	42.16	0.77679
62	50	49.76	0.48310
63	50	46.43	0.61737
64	50	41.83	0.78788
65	50	73.48	0.01694
66	50	59.83	0.16094
67	50	47.19	0.58674
68	50	60.35	0.14997
69	50	63.38	0.09677
70	50	36.52	0.92286
71	50	38.50	0.88183
72	50	54.09	0.32121
73	50	45.61	0.65009
74	50	41.57	0.79623
75	50	38.22	0.88822
76	50	32.75	0.97181
77	50	61.26	0.13216
78	50	36.14	0.92943

79	50	52.45	0.37913
80	50	44.31	0.70014
81	50	37.97	0.89389
82	50	37.11	0.91187
83	50	48.00	0.55400
84	50	68.33	0.04340
85	50	66.53	0.05889
86	50	41.08	0.81144
87	50	45.80	0.64244
88	50	53.87	0.32860
89	50	53.02	0.35833
90	50	65.95	0.06475
91	50	48.55	0.53170
92	50	59.72	0.16333
93	50	63.87	0.08989
94	50	65.79	0.06645
95	50	40.13	0.83945
96	50	48.99	0.51406
97	50	41.98	0.78294
98	50	52.73	0.36890
99	50	69.84	0.03331
100	50	47.07	0.59188
Combined P-value for all tests			0.70431

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	11.10	0.52032
2	12	7.03	0.85589
3	12	7.85	0.79670
4	12	10.00	0.61586
5	12	14.67	0.25977
6	12	10.46	0.57552
7	12	10.71	0.55387
8	12	8.58	0.73813
9	12	11.15	0.51652
10	12	14.20	0.28823
11	12	12.80	0.38362
12	12	7.57	0.81789
13	12	5.60	0.93506
14	12	5.61	0.93425
15	12	4.28	0.97779

16	12	27.97	0.00558
17	12	6.45	0.89174
18	12	9.60	0.65109
19	12	9.56	0.65450
20	12	13.83	0.31166
21	12	22.31	0.03419
22	12	10.05	0.61179
23	12	7.03	0.85574
24	12	6.96	0.86046
25	12	7.31	0.83662
26	12	7.43	0.82762
27	12	32.08	0.00134
28	12	5.51	0.93872
29	12	7.21	0.84341
30	12	12.70	0.39150
31	12	15.78	0.20165
32	12	11.84	0.45849
33	12	13.81	0.31273
34	12	12.83	0.38180
35	12	8.98	0.70451
36	12	15.62	0.20937
37	12	9.25	0.68133
38	12	10.96	0.53256
39	12	8.46	0.74837
40	12	7.97	0.78741
41	12	10.69	0.55557
42	12	14.83	0.25078
43	12	13.57	0.32897
44	12	22.08	0.03661
45	12	5.84	0.92415
46	12	22.41	0.03317
47	12	21.54	0.04302
48	12	6.91	0.86363
49	12	15.02	0.24017
50	12	12.94	0.37365
51	12	8.65	0.73223
52	12	4.92	0.96073
53	12	11.48	0.48796
54	12	8.55	0.74114
55	12	6.18	0.90656
56	12	3.52	0.99057
57	12	14.43	0.27419
58	12	10.59	0.56404
59	12	9.55	0.65507
60	12	6.57	0.88487
61	12	15.53	0.21355
62	12	24.15	0.01939
63	12	6.44	0.89230
64	12	10.63	0.56121
65	12	19.86	0.06980
66	12	5.48	0.93995
67	12	17.48	0.13230
68	12	13.71	0.31938
69	12	12.73	0.38906
70	12	6.41	0.89379

71	12	3.84	0.98615
72	12	5.92	0.92006
73	12	9.42	0.66696
74	12	20.28	0.06194
75	12	6.67	0.87858
76	12	9.14	0.69114
77	12	17.92	0.11817
78	12	6.96	0.86003
79	12	12.69	0.39223
80	12	17.94	0.11757
81	12	18.64	0.09767
82	12	10.31	0.58900
83	12	5.64	0.93297
84	12	6.02	0.91520
85	12	17.65	0.12666
86	12	10.18	0.60039
87	12	9.75	0.63830
88	12	11.42	0.49366
89	12	15.91	0.19537
90	12	21.35	0.04551
91	12	5.80	0.92599
92	12	9.05	0.69868
93	12	9.84	0.62975
94	12	9.13	0.69198
95	12	23.20	0.02607
96	12	13.46	0.33629
97	12	15.17	0.23247
98	12	6.40	0.89435
99	12	11.66	0.47367
100	12	13.84	0.31083
Combined P-value for all tests (Using KS method)			0.18320

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	12.34	0.41877
2	12	13.81	0.31314
3	12	14.38	0.27739
4	12	11.23	0.50938
5	12	14.17	0.29001
6	12	19.25	0.08269
7	12	12.67	0.39339
8	12	22.86	0.02895
9	12	11.26	0.50718
10	12	6.01	0.91580
11	12	11.46	0.48969
12	12	19.63	0.07442
13	12	14.51	0.26933
14	12	9.68	0.64412
15	12	8.43	0.75082

16	12	26.55	0.00896
17	12	11.75	0.46583
18	12	16.31	0.17760
19	12	17.07	0.14708
20	12	12.67	0.39357
21	12	6.65	0.87994
22	12	11.64	0.47496
23	12	17.56	0.12959
24	12	7.30	0.83744
25	12	14.72	0.25695
26	12	13.72	0.31922
27	12	9.79	0.63460
28	12	18.54	0.10025
29	12	9.17	0.68850
30	12	8.37	0.75526
31	12	8.54	0.74129
32	12	12.64	0.39607
33	12	11.22	0.51058
34	12	8.97	0.70572
35	12	5.60	0.93483
36	12	4.93	0.96035
37	12	3.98	0.98384
38	12	17.62	0.12779
39	12	8.27	0.76350
40	12	11.74	0.46699
41	12	10.25	0.59418
42	12	14.80	0.25265
43	12	9.91	0.62403
44	12	5.98	0.91722
45	12	7.72	0.80667
46	12	4.06	0.98241
47	12	12.16	0.43287
48	12	30.93	0.00202
49	12	13.82	0.31267
50	12	10.41	0.57971
51	12	13.66	0.32269
52	12	10.72	0.55276
53	12	10.68	0.55685
54	12	4.48	0.97317
55	12	17.94	0.11746
56	12	12.49	0.40688
57	12	8.12	0.77578
58	12	15.45	0.21759
59	12	10.40	0.58115
60	12	8.45	0.74908
61	12	9.48	0.66146
62	12	12.70	0.39126
63	12	8.87	0.71416
64	12	11.26	0.50718
65	12	15.53	0.21367
66	12	8.41	0.75198
67	12	8.93	0.70874
68	12	11.39	0.49543
69	12	4.25	0.97840
70	12	14.08	0.29579

71	12	7.83	0.79806
72	12	9.85	0.62901
73	12	13.18	0.35581
74	12	13.18	0.35615
75	12	6.28	0.90119
76	12	18.33	0.10611
77	12	8.63	0.73442
78	12	7.65	0.81197
79	12	4.75	0.96573
80	12	7.67	0.81056
81	12	5.06	0.95594
82	12	17.00	0.14955
83	12	11.38	0.49701
84	12	26.55	0.00897
85	12	11.47	0.48949
86	12	8.49	0.74578
87	12	12.07	0.43983
88	12	14.54	0.26780
89	12	28.63	0.00448
90	12	20.45	0.05900
91	12	13.72	0.31891
92	12	4.93	0.96035
93	12	11.98	0.44759
94	12	6.41	0.89417
95	12	11.36	0.49860
96	12	6.48	0.89008
97	12	11.89	0.45427
98	12	5.48	0.94016
99	12	14.58	0.26502
100	12	13.19	0.35504
Combined P-value for all tests (Using KS method)			0.65075

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)	0.66090	1.00000
Opening Score (Dealer)	0.19657	0.91599
Dealer's Final Score	0.70431	1.00000
Player Cards Rank	0.18320	0.91599
Dealer Cards Rank	0.65075	1.00000
Combined P-Value using Holm's Method		0.91599

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.

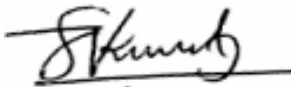
We conclude that the Random Number Generator (RNG) is working correctly.

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 February, 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.