



Blackjack Cards Analysis – January 2022

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **January 01, 2022 to January 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	8.58	0.95255
2	17	18.95	0.33153
3	17	12.28	0.78319
4	17	10.60	0.87639
5	17	15.95	0.52719
6	17	12.89	0.74367
7	17	11.63	0.82172
8	17	23.45	0.13524
9	17	11.91	0.80584
10	17	9.52	0.92261
11	17	23.95	0.12082
12	17	13.78	0.68280
13	17	20.77	0.23660
14	17	18.53	0.35624
15	17	13.22	0.72142
16	17	25.60	0.08214
17	17	20.04	0.27223
18	17	26.61	0.06405
19	17	18.56	0.35407
20	17	23.62	0.13017
21	17	32.04	0.01488
22	17	16.67	0.47674
23	17	16.07	0.51866

24	17	23.86	0.12340
25	17	22.17	0.17843
26	17	17.41	0.42698
27	17	16.08	0.51787
28	17	29.03	0.03425
29	17	15.68	0.54694
30	17	21.36	0.21043
31	17	16.75	0.47141
32	17	9.21	0.93350
33	17	11.75	0.81485
34	17	16.27	0.50462
35	17	18.88	0.33544
36	17	17.52	0.41941
37	17	13.46	0.70508
38	17	19.92	0.27842
39	17	18.82	0.33889
40	17	8.72	0.94862
41	17	15.69	0.54624
42	17	13.38	0.71028
43	17	13.71	0.68754
44	17	18.62	0.35053
45	17	15.29	0.57463
46	17	23.39	0.13698
47	17	23.61	0.13044
48	17	15.03	0.59328
49	17	10.68	0.87293
50	17	19.58	0.29628
51	17	12.48	0.77050
52	17	12.25	0.78451
53	17	12.32	0.78069
54	17	17.91	0.39453
55	17	11.28	0.84155
56	17	20.05	0.27153
57	17	16.28	0.50376
58	17	14.08	0.66117
59	17	10.89	0.86242
60	17	14.60	0.62430
61	17	18.83	0.33827
62	17	16.60	0.48183
63	17	6.76	0.98645
64	17	16.56	0.48431
65	17	10.84	0.86483
66	17	20.59	0.24521
67	17	15.38	0.56801
68	17	17.83	0.39969
69	17	9.20	0.93385
70	17	12.36	0.77817
71	17	28.77	0.03668
72	17	21.16	0.21931
73	17	25.04	0.09373
74	17	17.86	0.39788
75	17	17.94	0.39267
76	17	13.37	0.71100
77	17	25.07	0.09314
78	17	12.95	0.73962

79	17	21.46	0.20647
80	17	10.50	0.88124
81	17	18.61	0.35164
82	17	16.76	0.47053
83	17	6.70	0.98708
84	17	18.56	0.35437
85	17	25.11	0.09236
86	17	16.58	0.48296
87	17	20.11	0.26859
88	17	14.27	0.64776
89	17	14.27	0.64808
90	17	17.28	0.43531
91	17	15.37	0.56860
92	17	28.61	0.03828
93	17	15.39	0.56744
94	17	20.71	0.23938
95	17	29.75	0.02822
96	17	9.79	0.91232
97	17	8.13	0.96375
98	17	7.18	0.98105
99	17	19.10	0.32296
100	17	24.16	0.11524
Combined P-value for all tests (Using KS method)			0.98413

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	11.74	0.81582
2	17	15.21	0.58049
3	17	17.49	0.42144
4	17	13.44	0.70639
5	17	14.17	0.65527
6	17	21.28	0.21416
7	17	17.48	0.42202
8	17	17.15	0.44456
9	17	15.64	0.54978
10	17	10.51	0.88092
11	17	20.32	0.25834
12	17	13.37	0.71128
13	17	27.45	0.05173
14	17	13.29	0.71628
15	17	19.47	0.30202
16	17	15.71	0.54462
17	17	14.57	0.62637
18	17	14.11	0.65940
19	17	16.11	0.51579
20	17	24.18	0.11475
21	17	9.54	0.92172
22	17	20.29	0.25967
23	17	13.29	0.71624

24	17	22.13	0.17971
25	17	12.75	0.75295
26	17	13.54	0.69904
27	17	15.08	0.58999
28	17	12.43	0.77361
29	17	17.73	0.40633
30	17	13.11	0.72912
31	17	19.51	0.30020
32	17	17.74	0.40510
33	17	16.68	0.47615
34	17	16.85	0.46466
35	17	10.67	0.87318
36	17	20.74	0.23806
37	17	12.56	0.76488
38	17	11.35	0.83803
39	17	14.48	0.63257
40	17	24.42	0.10840
41	17	12.08	0.79544
42	17	13.83	0.67928
43	17	21.69	0.19688
44	17	15.89	0.53166
45	17	24.37	0.10982
46	17	10.56	0.87866
47	17	28.92	0.03529
48	17	11.13	0.84984
49	17	20.07	0.27044
50	17	15.75	0.54187
51	17	29.53	0.02998
52	17	18.40	0.36424
53	17	12.82	0.74834
54	17	13.48	0.70359
55	17	21.69	0.19705
56	17	20.97	0.22744
57	17	9.64	0.91784
58	17	13.10	0.72940
59	17	17.93	0.39298
60	17	21.77	0.19376
61	17	9.59	0.91991
62	17	11.51	0.82906
63	17	24.92	0.09662
64	17	19.89	0.27994
65	17	15.84	0.53526
66	17	16.01	0.52286
67	17	13.09	0.73042
68	17	16.61	0.48112
69	17	31.52	0.01724
70	17	18.57	0.35363
71	17	14.63	0.62246
72	17	11.89	0.80675
73	17	9.19	0.93422
74	17	12.02	0.79900
75	17	21.84	0.19101
76	17	24.28	0.11197
77	17	26.81	0.06097
78	17	19.58	0.29606

79	17	16.88	0.46258
80	17	12.43	0.77362
81	17	29.77	0.02803
82	17	26.65	0.06348
83	17	15.03	0.59306
84	17	22.57	0.16386
85	17	13.19	0.72309
86	17	18.17	0.37800
87	17	27.45	0.05182
88	17	18.53	0.35622
89	17	15.99	0.52467
90	17	21.86	0.18999
91	17	14.70	0.61730
92	17	21.49	0.20520
93	17	25.81	0.07793
94	17	22.54	0.16498
95	17	15.74	0.54218
96	17	10.38	0.88707
97	17	20.31	0.25887
98	17	20.77	0.23685
99	17	16.95	0.45790
100	17	8.28	0.96019
Combined P-value for all tests (Using KS method)			0.90001

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	51.96	0.39741
2	50	47.51	0.57394
3	50	46.71	0.60635
4	50	70.83	0.02785
5	50	47.74	0.56451
6	50	51.35	0.42052
7	50	47.01	0.59396
8	50	32.79	0.97141
9	50	90.99	0.00035
10	50	42.08	0.77942
11	50	37.24	0.90921
12	50	40.62	0.82528
13	50	59.15	0.17610
14	50	45.78	0.64335
15	50	43.09	0.74484
16	50	40.76	0.82126
17	50	43.45	0.73178
18	50	62.12	0.11669
19	50	47.04	0.59287
20	50	61.95	0.11971
21	50	44.93	0.67630
22	50	37.76	0.89850
23	50	53.74	0.33314

24	50	55.77	0.26688
25	50	42.57	0.76307
26	50	43.56	0.72779
27	50	65.87	0.06557
28	50	45.51	0.65382
29	50	47.26	0.58393
30	50	55.81	0.26566
31	50	70.06	0.03202
32	50	42.20	0.77553
33	50	52.50	0.37732
34	50	64.31	0.08403
35	50	54.07	0.32163
36	50	54.47	0.30833
37	50	51.85	0.40152
38	50	38.81	0.87433
39	50	40.49	0.82915
40	50	35.74	0.93599
41	50	32.43	0.97439
42	50	57.12	0.22754
43	50	67.66	0.04869
44	50	46.06	0.63205
45	50	50.84	0.44043
46	50	62.05	0.11790
47	50	55.57	0.27290
48	50	56.38	0.24866
49	50	47.80	0.56202
50	50	54.57	0.30502
51	50	54.74	0.29938
52	50	55.57	0.27317
53	50	45.87	0.63986
54	50	33.25	0.96724
55	50	58.57	0.18996
56	50	73.87	0.01572
57	50	60.64	0.14409
58	50	46.99	0.59483
59	50	47.89	0.55849
60	50	55.34	0.28015
61	50	34.81	0.94938
62	50	62.37	0.11262
63	50	70.10	0.03179
64	50	51.12	0.42938
65	50	64.54	0.08103
66	50	52.56	0.37530
67	50	41.79	0.78896
68	50	68.98	0.03878
69	50	44.56	0.69063
70	50	66.05	0.06371
71	50	39.98	0.84382
72	50	48.80	0.52152
73	50	56.82	0.23599
74	50	60.34	0.15009
75	50	48.94	0.51581
76	50	66.48	0.05931
77	50	52.97	0.36026
78	50	51.05	0.43202

79	50	42.63	0.76093
80	50	41.59	0.79559
81	50	55.60	0.27203
82	50	53.89	0.32803
83	50	70.38	0.03023
84	50	51.34	0.42112
85	50	46.07	0.63191
86	50	48.50	0.53392
87	50	54.60	0.30408
88	50	54.08	0.32155
89	50	49.96	0.47505
90	50	57.16	0.22642
91	50	59.87	0.16009
92	50	42.95	0.74976
93	50	54.05	0.32231
94	50	74.59	0.01365
95	50	48.86	0.51902
96	50	52.50	0.37725
97	50	64.21	0.08535
98	50	43.81	0.71877
99	50	60.09	0.15527
100	50	46.86	0.60027
Combined P-value for all tests			0.26078

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	11.94	0.45021
2	12	17.30	0.13867
3	12	7.56	0.81841
4	12	7.79	0.80141
5	12	18.82	0.09307
6	12	12.41	0.41307
7	12	5.91	0.92038
8	12	22.49	0.03240
9	12	8.20	0.76945
10	12	17.93	0.11787
11	12	13.69	0.32111
12	12	10.04	0.61236
13	12	20.63	0.05602
14	12	9.31	0.67627
15	12	7.01	0.85703

16	12	9.44	0.66498
17	12	14.47	0.27186
18	12	8.55	0.74087
19	12	13.30	0.34734
20	12	14.72	0.25686
21	12	7.80	0.80092
22	12	15.24	0.22852
23	12	13.49	0.33473
24	12	4.58	0.97053
25	12	12.89	0.37676
26	12	17.43	0.13407
27	12	12.17	0.43240
28	12	12.15	0.43343
29	12	11.27	0.50625
30	12	18.09	0.11295
31	12	10.76	0.54994
32	12	15.34	0.22344
33	12	3.92	0.98476
34	12	9.39	0.66922
35	12	6.25	0.90305
36	12	16.56	0.16689
37	12	15.17	0.23212
38	12	9.74	0.63887
39	12	24.78	0.01590
40	12	10.21	0.59754
41	12	13.50	0.33384
42	12	9.35	0.67317
43	12	3.97	0.98391
44	12	5.98	0.91732
45	12	10.22	0.59640
46	12	23.55	0.02337
47	12	9.19	0.68638
48	12	15.37	0.22177
49	12	12.62	0.39739
50	12	10.93	0.53508
51	12	7.53	0.82079
52	12	18.59	0.09895
53	12	11.20	0.51148
54	12	13.87	0.30912
55	12	10.21	0.59754
56	12	13.45	0.33740
57	12	12.88	0.37819
58	12	13.91	0.30680
59	12	6.86	0.86656
60	12	13.93	0.30512
61	12	20.62	0.05623
62	12	10.42	0.57934
63	12	17.47	0.13274
64	12	11.24	0.50845
65	12	13.33	0.34552
66	12	9.30	0.67712
67	12	7.13	0.84919
68	12	12.34	0.41913
69	12	19.35	0.08037
70	12	10.31	0.58900

71	12	10.27	0.59213
72	12	5.98	0.91716
73	12	6.06	0.91304
74	12	14.86	0.24896
75	12	8.00	0.78513
76	12	8.45	0.74944
77	12	9.16	0.68891
78	12	2.55	0.99797
79	12	8.60	0.73629
80	12	10.94	0.53424
81	12	8.81	0.71941
82	12	17.90	0.11868
83	12	7.22	0.84274
84	12	9.38	0.67007
85	12	13.63	0.32524
86	12	12.02	0.44432
87	12	7.34	0.83456
88	12	17.29	0.13906
89	12	9.96	0.61949
90	12	18.09	0.11285
91	12	13.29	0.34802
92	12	14.34	0.27928
93	12	5.96	0.91830
94	12	23.91	0.02091
95	12	8.13	0.77489
96	12	9.38	0.67035
97	12	18.70	0.09597
98	12	13.89	0.30806
99	12	11.03	0.52616
100	12	19.41	0.07919
Combined P-value for all tests (Using KS method)			0.99357

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	9.53	0.65755
2	12	10.37	0.58384
3	12	7.94	0.78987
4	12	7.89	0.79353
5	12	17.84	0.12070
6	12	4.82	0.96361
7	12	15.18	0.23167
8	12	5.57	0.93636
9	12	9.71	0.64143
10	12	11.46	0.49008
11	12	13.83	0.31159
12	12	9.48	0.66167
13	12	13.13	0.35935
14	12	7.65	0.81179
15	12	20.17	0.06392

16	12	5.23	0.95001
17	12	8.57	0.73914
18	12	10.69	0.55603
19	12	4.29	0.97768
20	12	19.65	0.07403
21	12	6.26	0.90249
22	12	26.80	0.00826
23	12	11.24	0.50858
24	12	8.57	0.73894
25	12	17.52	0.13118
26	12	11.94	0.45045
27	12	8.84	0.71656
28	12	10.97	0.53176
29	12	7.43	0.82770
30	12	4.33	0.97672
31	12	8.35	0.75719
32	12	7.20	0.84433
33	12	22.42	0.03309
34	12	15.33	0.22400
35	12	13.95	0.30392
36	12	11.63	0.47555
37	12	10.68	0.55624
38	12	5.14	0.95303
39	12	13.03	0.36684
40	12	10.76	0.54948
41	12	14.89	0.24774
42	12	7.31	0.83661
43	12	6.82	0.86921
44	12	12.77	0.38595
45	12	2.90	0.99623
46	12	12.92	0.37511
47	12	17.10	0.14603
48	12	17.27	0.13986
49	12	11.40	0.49463
50	12	16.78	0.15791
51	12	16.76	0.15903
52	12	11.61	0.47711
53	12	10.93	0.53480
54	12	11.71	0.46932
55	12	13.57	0.32921
56	12	9.84	0.63025
57	12	12.38	0.41600
58	12	4.86	0.96259
59	12	11.71	0.46912
60	12	6.78	0.87160
61	12	9.40	0.66825
62	12	4.46	0.97376
63	12	29.70	0.00310
64	12	11.76	0.46486
65	12	8.27	0.76388
66	12	23.13	0.02662
67	12	10.96	0.53216
68	12	7.81	0.80005
69	12	8.92	0.70935
70	12	5.92	0.91992

71	12	8.15	0.77297
72	12	3.94	0.98450
73	12	5.66	0.93232
74	12	9.79	0.63481
75	12	9.10	0.69399
76	12	12.18	0.43119
77	12	11.41	0.49404
78	12	10.58	0.56507
79	12	20.40	0.05997
80	12	15.11	0.23546
81	12	13.55	0.33066
82	12	22.84	0.02910
83	12	13.71	0.31985
84	12	6.79	0.87100
85	12	17.83	0.12092
86	12	10.13	0.60435
87	12	9.37	0.67107
88	12	5.29	0.94759
89	12	14.75	0.25567
90	12	12.68	0.39286
91	12	19.12	0.08563
92	12	10.48	0.57420
93	12	6.91	0.86347
94	12	8.22	0.76778
95	12	7.13	0.84924
96	12	16.43	0.17247
97	12	18.16	0.11092
98	12	13.39	0.34157
99	12	15.52	0.21407
100	12	8.69	0.72912
Combined P-value for all tests (Using KS method)			0.45069

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)	0.98413	1.00000
Opening Score (Dealer)	0.90001	1.00000
Dealer's Final Score	0.26078	1.00000
Player Cards Rank	0.99357	1.00000
Dealer Cards Rank	0.45069	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.

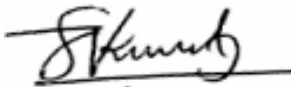
We conclude that the Random Number Generator (RNG) is working correctly.

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:



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iTech Labs Australia
Date: 01 March, 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.