

Blackjack Cards Analysis – November 2021

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **November 01, 2021 to November 30, 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	19.82	0.28361
2	17	29.28	0.03199
3	17	20.38	0.25528
4	17	12.45	0.77201
5	17	15.32	0.57278
6	17	9.53	0.92227
7	17	15.23	0.57923
8	17	14.14	0.65695
9	17	12.21	0.78739
10	17	30.56	0.02255
11	17	7.56	0.97512
12	17	15.72	0.54365
13	17	15.48	0.56097
14	17	13.37	0.71102
15	17	16.03	0.52155
16	17	21.49	0.20519
17	17	35.31	0.00567
18	17	20.56	0.24676
19	17	12.73	0.75390
20	17	27.33	0.05346
21	17	24.04	0.11844
22	17	15.89	0.53165
23	17	6.25	0.99137

24	17	7.15	0.98147
25	17	18.66	0.34851
26	17	12.42	0.77383
27	17	14.70	0.61680
28	17	13.90	0.67451
29	17	17.83	0.39994
30	17	13.90	0.67429
31	17	16.02	0.52240
32	17	23.35	0.13823
33	17	11.33	0.83908
34	17	14.15	0.65618
35	17	18.84	0.33783
36	17	12.81	0.74859
37	17	12.35	0.77874
38	17	7.53	0.97561
39	17	11.84	0.81002
40	17	18.17	0.37807
41	17	10.90	0.86146
42	17	14.64	0.62136
43	17	22.46	0.16781
44	17	9.88	0.90860
45	17	27.66	0.04911
46	17	14.25	0.64904
47	17	16.39	0.49610
48	17	13.53	0.70030
49	17	17.96	0.39116
50	17	29.52	0.03003
51	17	27.93	0.04577
52	17	8.33	0.95909
53	17	21.50	0.20471
54	17	12.01	0.79944
55	17	12.84	0.74690
56	17	12.95	0.73934
57	17	14.58	0.62569
58	17	17.17	0.44263
59	17	14.37	0.64084
60	17	15.03	0.59301
61	17	12.84	0.74657
62	17	15.47	0.56166
63	17	20.65	0.24244
64	17	18.57	0.35359
65	17	16.52	0.48707
66	17	11.29	0.84105
67	17	12.66	0.75857
68	17	9.46	0.92488
69	17	8.61	0.95164
70	17	16.06	0.51945
71	17	8.22	0.96172
72	17	10.98	0.85766
73	17	15.40	0.56703
74	17	8.95	0.94179
75	17	13.64	0.69264
76	17	12.71	0.75527
77	17	28.20	0.04267
78	17	22.12	0.18012

79	17	20.13	0.26772
80	17	11.49	0.83004
81	17	16.81	0.46760
82	17	6.51	0.98908
83	17	14.24	0.65035
84	17	17.39	0.42800
85	17	19.25	0.31465
86	17	15.61	0.55194
87	17	16.36	0.49867
88	17	22.22	0.17624
89	17	16.89	0.46192
90	17	17.81	0.40065
91	17	12.48	0.77034
92	17	7.37	0.97815
93	17	20.26	0.26110
94	17	15.48	0.56111
95	17	23.98	0.11995
96	17	11.67	0.81974
97	17	16.56	0.48460
98	17	25.52	0.08362
99	17	28.56	0.03879
100	17	7.58	0.97465
Combined P-value for all tests (Using KS method)			0.08260

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	21.20	0.21753
2	17	21.49	0.20494
3	17	31.96	0.01521
4	17	13.95	0.67079
5	17	20.65	0.24256
6	17	14.88	0.60440
7	17	17.63	0.41280
8	17	17.31	0.43359
9	17	14.95	0.59886
10	17	25.93	0.07583
11	17	8.62	0.95148
12	17	14.39	0.63967
13	17	22.01	0.18433
14	17	32.58	0.01275
15	17	9.11	0.93662
16	17	17.36	0.42992
17	17	10.75	0.86936
18	17	16.86	0.46392
19	17	16.45	0.49227
20	17	12.84	0.74663
21	17	14.95	0.59891
22	17	9.80	0.91194
23	17	25.35	0.08705

24	17	29.16	0.03305
25	17	19.03	0.32695
26	17	21.54	0.20307
27	17	6.88	0.98500
28	17	10.90	0.86191
29	17	9.43	0.92572
30	17	19.84	0.28256
31	17	14.33	0.64356
32	17	16.19	0.51067
33	17	19.98	0.27511
34	17	17.09	0.44811
35	17	23.60	0.13076
36	17	14.29	0.64681
37	17	14.06	0.66282
38	17	24.06	0.11772
39	17	34.30	0.00767
40	17	14.53	0.62915
41	17	6.37	0.99037
42	17	9.79	0.91224
43	17	22.05	0.18290
44	17	16.52	0.48723
45	17	18.53	0.35635
46	17	6.98	0.98381
47	17	19.54	0.29859
48	17	17.33	0.43242
49	17	16.09	0.51724
50	17	15.26	0.57700
51	17	13.88	0.67546
52	17	12.90	0.74275
53	17	27.91	0.04598
54	17	20.87	0.23231
55	17	15.74	0.54199
56	17	15.07	0.59020
57	17	16.32	0.50125
58	17	18.74	0.34343
59	17	14.05	0.66332
60	17	15.03	0.59343
61	17	17.63	0.41261
62	17	26.71	0.06246
63	17	17.92	0.39374
64	17	14.79	0.61064
65	17	17.10	0.44793
66	17	5.48	0.99606
67	17	12.63	0.76043
68	17	6.82	0.98574
69	17	12.76	0.75239
70	17	21.74	0.19504
71	17	20.77	0.23679
72	17	10.94	0.85982
73	17	16.49	0.48931
74	17	21.29	0.21380
75	17	18.02	0.38782
76	17	39.94	0.00132
77	17	23.72	0.12722
78	17	13.04	0.73368

79	17	23.22	0.14226
80	17	22.33	0.17239
81	17	18.72	0.34502
82	17	20.34	0.25704
83	17	15.01	0.59509
84	17	16.76	0.47052
85	17	22.18	0.17777
86	17	12.93	0.74093
87	17	12.89	0.74364
88	17	20.03	0.27253
89	17	20.81	0.23502
90	17	26.04	0.07381
91	17	17.57	0.41632
92	17	33.05	0.01111
93	17	18.34	0.36796
94	17	16.86	0.46372
95	17	25.92	0.07593
96	17	15.96	0.52676
97	17	19.37	0.30792
98	17	27.92	0.04591
99	17	14.35	0.64225
100	17	16.61	0.48128
Combined P-value for all tests (Using KS method)			0.13528

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	69.28	0.03678
2	50	49.51	0.49283
3	50	41.02	0.81340
4	50	61.78	0.12261
5	50	30.69	0.98565
6	50	70.68	0.02862
7	50	58.74	0.18582
8	50	58.58	0.18954
9	50	30.72	0.98551
10	50	47.81	0.56153
11	50	56.03	0.25891
12	50	40.33	0.83396
13	50	56.35	0.24952
14	50	33.14	0.96822
15	50	62.91	0.10388
16	50	44.24	0.70290
17	50	65.47	0.06991
18	50	53.69	0.33476
19	50	35.16	0.94455
20	50	45.61	0.65009
21	50	60.34	0.15018
22	50	58.60	0.18914
23	50	60.29	0.15112

24	50	32.74	0.97183
25	50	50.81	0.44168
26	50	44.70	0.68532
27	50	47.57	0.57150
28	50	52.32	0.38411
29	50	44.27	0.70159
30	50	34.77	0.94993
31	50	46.22	0.62569
32	50	48.52	0.53281
33	50	50.10	0.46957
34	50	50.03	0.47218
35	50	76.57	0.00919
36	50	51.89	0.40000
37	50	62.34	0.11310
38	50	74.44	0.01407
39	50	55.71	0.26877
40	50	35.55	0.93885
41	50	45.50	0.65450
42	50	49.37	0.49840
43	50	39.76	0.84986
44	50	64.43	0.08237
45	50	36.32	0.92640
46	50	37.75	0.89877
47	50	55.02	0.29051
48	50	51.88	0.40061
49	50	46.92	0.59754
50	50	46.72	0.60562
51	50	54.98	0.29168
52	50	64.23	0.08502
53	50	66.87	0.05563
54	50	54.85	0.29597
55	50	50.59	0.45022
56	50	62.56	0.10946
57	50	54.37	0.31155
58	50	59.07	0.17809
59	50	46.92	0.59792
60	50	51.73	0.40608
61	50	38.76	0.87567
62	50	46.57	0.61198
63	50	35.35	0.94186
64	50	70.70	0.02855
65	50	56.89	0.23394
66	50	40.06	0.84145
67	50	43.76	0.72042
68	50	41.38	0.80217
69	50	57.96	0.20527
70	50	63.15	0.10030
71	50	37.56	0.90280
72	50	52.14	0.39070
73	50	61.61	0.12574
74	50	51.45	0.41668
75	50	44.06	0.70932
76	50	49.35	0.49952
77	50	50.48	0.45432
78	50	52.35	0.38303

79	50	45.08	0.67053
80	50	32.98	0.96973
81	50	39.88	0.84643
82	50	55.84	0.26488
83	50	62.25	0.11450
84	50	36.00	0.93174
85	50	60.01	0.15699
86	50	55.82	0.26547
87	50	88.50	0.00065
88	50	32.76	0.97168
89	50	59.57	0.16663
90	50	67.17	0.05287
91	50	50.71	0.44522
92	50	62.26	0.11446
93	50	60.45	0.14778
94	50	61.15	0.13423
95	50	51.68	0.40818
96	50	65.91	0.06509
97	50	73.12	0.01815
98	50	58.47	0.19226
99	50	43.28	0.73790
100	50	52.66	0.37137
Combined P-value for all tests			0.11616

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	5.18	0.95161
2	12	8.08	0.77849
3	12	11.32	0.50213
4	12	10.93	0.53480
5	12	14.95	0.24444
6	12	9.36	0.67204
7	12	10.67	0.55783
8	12	11.33	0.50076
9	12	5.75	0.92811
10	12	11.84	0.45876
11	12	12.81	0.38276
12	12	9.59	0.65195
13	12	16.96	0.15122
14	12	18.13	0.11170
15	12	20.66	0.05566

16	12	9.72	0.64086
17	12	11.69	0.47126
18	12	8.79	0.72078
19	12	11.86	0.45717
20	12	14.27	0.28365
21	12	12.24	0.42650
22	12	6.96	0.86046
23	12	5.41	0.94274
24	12	11.80	0.46193
25	12	7.74	0.80486
26	12	11.36	0.49858
27	12	4.74	0.96610
28	12	5.58	0.93595
29	12	9.01	0.70201
30	12	12.67	0.39346
31	12	6.50	0.88871
32	12	21.75	0.04045
33	12	5.20	0.95114
34	12	8.69	0.72951
35	12	4.27	0.97815
36	12	5.56	0.93651
37	12	6.64	0.88017
38	12	12.77	0.38590
39	12	23.21	0.02600
40	12	10.55	0.56772
41	12	10.41	0.58019
42	12	16.48	0.17039
43	12	14.20	0.28806
44	12	11.35	0.49912
45	12	12.15	0.43369
46	12	8.62	0.73494
47	12	7.55	0.81889
48	12	7.21	0.84364
49	12	11.20	0.51175
50	12	23.67	0.02256
51	12	13.00	0.36891
52	12	8.89	0.71253
53	12	17.18	0.14279
54	12	8.99	0.70396
55	12	12.96	0.37199
56	12	4.21	0.97934
57	12	22.13	0.03606
58	12	7.67	0.81049
59	12	11.73	0.46760
60	12	23.07	0.02715
61	12	12.30	0.42174
62	12	14.27	0.28384
63	12	4.94	0.96001
64	12	38.68	0.00012
65	12	11.36	0.49833
66	12	7.14	0.84806
67	12	7.82	0.79893
68	12	21.00	0.05042
69	12	22.99	0.02780
70	12	8.51	0.74373

71	12	9.71	0.64158
72	12	13.22	0.35300
73	12	24.37	0.01808
74	12	18.02	0.11494
75	12	9.38	0.67056
76	12	20.76	0.05400
77	12	12.44	0.41119
78	12	9.03	0.70046
79	12	7.84	0.79783
80	12	8.66	0.73174
81	12	8.58	0.73799
82	12	9.54	0.65623
83	12	10.57	0.56645
84	12	16.31	0.17737
85	12	7.90	0.79317
86	12	11.81	0.46098
87	12	7.76	0.80376
88	12	10.97	0.53172
89	12	14.43	0.27403
90	12	6.43	0.89310
91	12	11.63	0.47545
92	12	7.56	0.81883
93	12	12.52	0.40497
94	12	21.75	0.04037
95	12	3.55	0.99031
96	12	16.98	0.15049
97	12	22.14	0.03603
98	12	10.24	0.59472
99	12	20.33	0.06104
100	12	12.20	0.43003
Combined P-value for all tests (Using KS method)			0.26776

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	4.57	0.97074
2	12	4.60	0.97011
3	12	20.77	0.05383
4	12	11.57	0.48044
5	12	17.68	0.12577
6	12	7.11	0.84998
7	12	6.69	0.87763
8	12	16.97	0.15071
9	12	10.41	0.57971
10	12	12.93	0.37407
11	12	8.20	0.76957
12	12	14.44	0.27369
13	12	9.35	0.67235
14	12	4.96	0.95935
15	12	17.24	0.14079

16	12	7.67	0.81003
17	12	21.48	0.04374
18	12	10.20	0.59812
19	12	22.05	0.03702
20	12	7.28	0.83865
21	12	7.53	0.82069
22	12	5.27	0.94833
23	12	11.44	0.49155
24	12	15.48	0.21614
25	12	6.96	0.86037
26	12	8.26	0.76412
27	12	10.49	0.57269
28	12	6.98	0.85866
29	12	16.89	0.15378
30	12	5.29	0.94759
31	12	4.61	0.96977
32	12	11.07	0.52289
33	12	10.70	0.55498
34	12	20.01	0.06698
35	12	12.02	0.44429
36	12	12.23	0.42707
37	12	7.90	0.79318
38	12	19.52	0.07676
39	12	17.65	0.12665
40	12	5.58	0.93575
41	12	18.14	0.11162
42	12	9.13	0.69186
43	12	15.48	0.21603
44	12	8.90	0.71112
45	12	12.86	0.37897
46	12	6.58	0.88388
47	12	7.42	0.82868
48	12	8.74	0.72485
49	12	15.40	0.22020
50	12	13.59	0.32778
51	12	7.00	0.85780
52	12	11.46	0.48956
53	12	25.88	0.01115
54	12	16.55	0.16750
55	12	10.65	0.55911
56	12	5.29	0.94759
57	12	11.38	0.49627
58	12	7.79	0.80131
59	12	7.45	0.82681
60	12	14.74	0.25592
61	12	6.05	0.91341
62	12	4.53	0.97200
63	12	10.58	0.56533
64	12	7.54	0.82021
65	12	6.54	0.88646
66	12	14.43	0.27417
67	12	16.21	0.18162
68	12	8.09	0.77795
69	12	11.25	0.50741
70	12	9.70	0.64216

71	12	19.45	0.07830
72	12	11.28	0.50521
73	12	11.41	0.49427
74	12	14.63	0.26228
75	12	7.10	0.85100
76	12	3.69	0.98836
77	12	19.68	0.07346
78	12	13.46	0.33679
79	12	9.71	0.64178
80	12	18.14	0.11137
81	12	5.27	0.94842
82	12	15.09	0.23669
83	12	18.07	0.11349
84	12	13.46	0.33634
85	12	20.60	0.05663
86	12	10.40	0.58064
87	12	8.70	0.72867
88	12	18.75	0.09482
89	12	4.23	0.97882
90	12	13.89	0.30811
91	12	12.18	0.43100
92	12	13.03	0.36692
93	12	10.06	0.61100
94	12	10.39	0.58177
95	12	14.98	0.24246
96	12	11.54	0.48342
97	12	14.73	0.25678
98	12	19.04	0.08753
99	12	10.52	0.57080
100	12	17.50	0.13179
Combined P-value for all tests (Using KS method)			0.46194

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)	0.08260	0.41300
Opening Score (Dealer)	0.13528	0.46463
Dealer's Final Score	0.11616	0.46463
Player Cards Rank	0.26776	0.53553
Dealer Cards Rank	0.46194	0.53553
Combined P-Value using Holm's Method		0.41300

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.

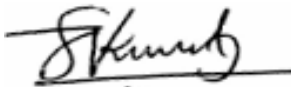
We conclude that the Random Number Generator (RNG) is working correctly.

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: 04 January, 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.