



Blackjack Cards Analysis – October 2021

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **October 01, 2021 to October 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	13.54	0.69962
2	17	12.91	0.74245
3	17	6.42	0.98990
4	17	13.41	0.70803
5	17	7.42	0.97750
6	17	15.30	0.57364
7	17	35.38	0.00555
8	17	23.13	0.14505
9	17	9.55	0.92141
10	17	14.87	0.60469
11	17	16.13	0.51468
12	17	25.83	0.07768
13	17	19.53	0.29893
14	17	16.31	0.50226
15	17	13.95	0.67032
16	17	15.49	0.56039
17	17	26.37	0.06801
18	17	11.37	0.83696
19	17	12.36	0.77757
20	17	12.34	0.77905
21	17	9.74	0.91410
22	17	14.12	0.65844
23	17	12.47	0.77113

24	17	8.39	0.95749
25	17	17.37	0.42989
26	17	11.86	0.80831
27	17	24.90	0.09700
28	17	5.65	0.99527
29	17	16.46	0.49171
30	17	16.87	0.46304
31	17	24.46	0.10748
32	17	15.61	0.55155
33	17	22.80	0.15594
34	17	16.06	0.51952
35	17	14.29	0.64630
36	17	15.98	0.52555
37	17	11.61	0.82339
38	17	10.41	0.88569
39	17	12.97	0.73843
40	17	22.14	0.17936
41	17	24.07	0.11761
42	17	22.79	0.15626
43	17	20.65	0.24238
44	17	16.17	0.51212
45	17	17.09	0.44833
46	17	19.08	0.32387
47	17	15.70	0.54484
48	17	15.85	0.53477
49	17	10.40	0.88604
50	17	14.48	0.63293
51	17	21.93	0.18758
52	17	22.36	0.17109
53	17	14.48	0.63315
54	17	15.99	0.52485
55	17	16.76	0.47078
56	17	18.15	0.37951
57	17	19.77	0.28599
58	17	14.74	0.61408
59	17	10.75	0.86912
60	17	11.13	0.84958
61	17	16.67	0.47695
62	17	11.25	0.84349
63	17	16.08	0.51843
64	17	13.80	0.68086
65	17	26.98	0.05830
66	17	17.52	0.41989
67	17	8.39	0.95746
68	17	12.23	0.78624
69	17	9.43	0.92587
70	17	23.33	0.13878
71	17	19.25	0.31416
72	17	10.72	0.87062
73	17	10.65	0.87440
74	17	16.39	0.49619
75	17	13.41	0.70804
76	17	9.46	0.92465
77	17	16.13	0.51438
78	17	17.04	0.45186

79	17	14.37	0.64047
80	17	8.83	0.94551
81	17	22.38	0.17071
82	17	11.28	0.84157
83	17	11.28	0.84140
84	17	17.96	0.39144
85	17	26.64	0.06356
86	17	11.66	0.82025
87	17	13.46	0.70482
88	17	17.19	0.44168
89	17	12.09	0.79484
90	17	16.92	0.45991
91	17	11.63	0.82198
92	17	17.72	0.40673
93	17	17.89	0.39571
94	17	16.43	0.49369
95	17	10.26	0.89219
96	17	30.91	0.02048
97	17	22.17	0.17827
98	17	21.97	0.18577
99	17	22.76	0.15734
100	17	12.17	0.78974
Combined P-value for all tests (Using KS method)			0.05691

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	22.64	0.16150
2	17	23.08	0.14676
3	17	11.34	0.83843
4	17	22.06	0.18226
5	17	24.10	0.11675
6	17	24.27	0.11240
7	17	17.33	0.43200
8	17	6.56	0.98860
9	17	22.16	0.17850
10	17	14.17	0.65520
11	17	16.13	0.51440
12	17	18.40	0.36431
13	17	23.75	0.12651
14	17	30.57	0.02252
15	17	12.29	0.78223
16	17	15.09	0.58927
17	17	17.20	0.44059
18	17	23.43	0.13581
19	17	15.58	0.55398
20	17	9.16	0.93499
21	17	24.69	0.10192
22	17	15.91	0.53023
23	17	15.12	0.58707

24	17	13.14	0.72702
25	17	27.12	0.05636
26	17	13.36	0.71172
27	17	13.14	0.72648
28	17	22.08	0.18153
29	17	13.74	0.68531
30	17	16.33	0.50034
31	17	15.39	0.56744
32	17	8.40	0.95731
33	17	17.80	0.40154
34	17	16.70	0.47494
35	17	28.52	0.03926
36	17	8.39	0.95750
37	17	31.89	0.01551
38	17	21.63	0.19941
39	17	10.60	0.87642
40	17	18.63	0.35033
41	17	22.20	0.17724
42	17	16.34	0.50013
43	17	13.75	0.68448
44	17	15.20	0.58114
45	17	17.92	0.39386
46	17	22.65	0.16085
47	17	10.54	0.87926
48	17	9.91	0.90731
49	17	10.09	0.89994
50	17	14.76	0.61246
51	17	16.10	0.51692
52	17	19.64	0.29315
53	17	15.52	0.55807
54	17	19.83	0.28320
55	17	20.36	0.25602
56	17	20.22	0.26336
57	17	26.95	0.05887
58	17	12.68	0.75725
59	17	13.37	0.71103
60	17	12.43	0.77346
61	17	10.17	0.89619
62	17	14.28	0.64749
63	17	19.55	0.29798
64	17	12.18	0.78931
65	17	9.97	0.90505
66	17	11.52	0.82849
67	17	14.04	0.66446
68	17	24.49	0.10674
69	17	16.19	0.51030
70	17	25.07	0.09305
71	17	10.97	0.85816
72	17	6.61	0.98808
73	17	10.00	0.90357
74	17	23.03	0.14820
75	17	12.59	0.76317
76	17	10.57	0.87821
77	17	21.17	0.21860
78	17	15.42	0.56531

79	17	13.09	0.73033
80	17	18.68	0.34706
81	17	15.83	0.53626
82	17	19.65	0.29232
83	17	21.12	0.22093
84	17	22.23	0.17597
85	17	11.44	0.83292
86	17	22.27	0.17451
87	17	16.55	0.48508
88	17	25.51	0.08388
89	17	9.70	0.91581
90	17	9.02	0.93964
91	17	5.97	0.99339
92	17	18.07	0.38421
93	17	15.86	0.53384
94	17	25.94	0.07549
95	17	19.43	0.30430
96	17	14.10	0.65998
97	17	24.12	0.11616
98	17	17.64	0.41172
99	17	10.17	0.89623
100	17	15.56	0.55546
Combined P-value for all tests (Using KS method)			0.88354

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	39.15	0.86595
2	50	39.22	0.86407
3	50	51.32	0.42160
4	50	45.74	0.64474
5	50	49.41	0.49690
6	50	61.72	0.12376
7	50	42.77	0.75604
8	50	52.69	0.37043
9	50	30.52	0.98650
10	50	50.59	0.45027
11	50	47.47	0.57545
12	50	36.65	0.92041
13	50	34.58	0.95244
14	50	32.79	0.97140
15	50	53.48	0.34225
16	50	38.21	0.88849
17	50	34.75	0.95019
18	50	44.51	0.69260
19	50	33.78	0.96184
20	50	61.66	0.12474
21	50	61.80	0.12222
22	50	49.37	0.49873
23	50	42.93	0.75044

24	50	52.12	0.39144
25	50	45.97	0.63563
26	50	55.27	0.28245
27	50	56.08	0.25739
28	50	54.86	0.29539
29	50	76.27	0.00976
30	50	46.85	0.60058
31	50	68.00	0.04596
32	50	48.25	0.54401
33	50	70.07	0.03198
34	50	71.11	0.02648
35	50	61.34	0.13050
36	50	51.41	0.41813
37	50	44.23	0.70307
38	50	55.66	0.27011
39	50	42.75	0.75680
40	50	41.31	0.80434
41	50	47.80	0.56213
42	50	50.02	0.47253
43	50	46.13	0.62952
44	50	55.03	0.28999
45	50	64.16	0.08590
46	50	50.61	0.44922
47	50	55.57	0.27305
48	50	44.26	0.70193
49	50	55.89	0.26333
50	50	37.59	0.90213
51	50	45.49	0.65456
52	50	56.75	0.23809
53	50	56.58	0.24281
54	50	46.43	0.61746
55	50	51.86	0.40115
56	50	55.74	0.26771
57	50	54.01	0.32373
58	50	52.89	0.36328
59	50	38.70	0.87708
60	50	44.21	0.70386
61	50	44.97	0.67492
62	50	51.86	0.40107
63	50	46.74	0.60481
64	50	57.64	0.21348
65	50	53.96	0.32556
66	50	39.71	0.85116
67	50	49.55	0.49120
68	50	53.48	0.34223
69	50	50.29	0.46183
70	50	71.47	0.02478
71	50	38.09	0.89132
72	50	44.41	0.69654
73	50	40.71	0.82277
74	50	48.42	0.53683
75	50	58.39	0.19431
76	50	39.27	0.86292
77	50	53.05	0.35724
78	50	46.06	0.63226

79	50	63.61	0.09354
80	50	52.09	0.39261
81	50	68.35	0.04327
82	50	40.06	0.84156
83	50	48.98	0.51431
84	50	33.59	0.96376
85	50	37.33	0.90749
86	50	49.13	0.50805
87	50	40.68	0.82363
88	50	60.54	0.14610
89	50	40.39	0.83220
90	50	54.05	0.32260
91	50	49.24	0.50381
92	50	58.29	0.19685
93	50	47.87	0.55917
94	50	46.20	0.62649
95	50	78.10	0.00670
96	50	52.84	0.36509
97	50	41.61	0.79488
98	50	38.05	0.89204
99	50	54.03	0.32320
100	50	62.94	0.10340
Combined P-value for all tests			0.87912

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	12.02	0.44424
2	12	10.53	0.56937
3	12	7.46	0.82601
4	12	9.39	0.66946
5	12	8.67	0.73071
6	12	13.25	0.35105
7	12	8.72	0.72667
8	12	11.05	0.52444
9	12	15.18	0.23180
10	12	13.02	0.36753
11	12	16.77	0.15851
12	12	17.39	0.13567
13	12	15.12	0.23477
14	12	13.14	0.35897
15	12	18.61	0.09846

16	12	13.82	0.31214
17	12	7.28	0.83841
18	12	7.57	0.81762
19	12	10.63	0.56096
20	12	9.01	0.70244
21	12	11.94	0.45081
22	12	12.89	0.37675
23	12	20.18	0.06372
24	12	6.95	0.86103
25	12	13.95	0.30419
26	12	5.58	0.93555
27	12	16.13	0.18553
28	12	7.06	0.85391
29	12	35.11	0.00045
30	12	12.98	0.37077
31	12	9.58	0.65263
32	12	11.86	0.45683
33	12	10.69	0.55580
34	12	14.66	0.26041
35	12	7.02	0.85614
36	12	14.40	0.27619
37	12	5.17	0.95223
38	12	17.10	0.14591
39	12	12.35	0.41782
40	12	12.92	0.37457
41	12	8.60	0.73690
42	12	13.40	0.34093
43	12	11.35	0.49955
44	12	12.75	0.38777
45	12	6.97	0.85957
46	12	7.84	0.79755
47	12	16.19	0.18256
48	12	9.78	0.63540
49	12	7.85	0.79641
50	12	21.78	0.04003
51	12	15.46	0.21718
52	12	12.83	0.38169
53	12	8.40	0.75312
54	12	15.02	0.24039
55	12	13.27	0.34975
56	12	8.94	0.70783
57	12	9.79	0.63410
58	12	16.45	0.17168
59	12	7.94	0.78954
60	12	6.57	0.88473
61	12	8.43	0.75039
62	12	8.03	0.78316
63	12	10.53	0.56937
64	12	17.81	0.12151
65	12	13.57	0.32897
66	12	8.36	0.75645
67	12	3.50	0.99081
68	12	7.29	0.83789
69	12	6.42	0.89363
70	12	12.99	0.36941

71	12	12.34	0.41840
72	12	11.02	0.52730
73	12	15.46	0.21699
74	12	24.55	0.01711
75	12	17.31	0.13814
76	12	12.52	0.40520
77	12	6.52	0.88759
78	12	7.77	0.80264
79	12	8.34	0.75766
80	12	8.23	0.76695
81	12	11.24	0.50833
82	12	18.99	0.08866
83	12	13.01	0.36844
84	12	9.52	0.65762
85	12	10.10	0.60723
86	12	3.35	0.99254
87	12	6.79	0.87111
88	12	7.98	0.78640
89	12	15.74	0.20336
90	12	12.32	0.42065
91	12	18.48	0.10184
92	12	9.79	0.63460
93	12	10.65	0.55924
94	12	9.43	0.66583
95	12	16.07	0.18792
96	12	15.48	0.21615
97	12	5.07	0.95554
98	12	9.02	0.70090
99	12	9.97	0.61864
100	12	8.42	0.75115
Combined P-value for all tests (Using KS method)			0.84066

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	9.61	0.65013
2	12	11.36	0.49858
3	12	11.91	0.45327
4	12	22.56	0.03175
5	12	7.61	0.81516
6	12	7.21	0.84377
7	12	8.80	0.72001
8	12	11.80	0.46194
9	12	15.11	0.23539
10	12	17.70	0.12507
11	12	8.81	0.71935
12	12	14.65	0.26121
13	12	20.52	0.05792
14	12	9.64	0.64763
15	12	25.50	0.01262

16	12	14.69	0.25910
17	12	11.83	0.45939
18	12	6.13	0.90919
19	12	15.40	0.22041
20	12	10.24	0.59521
21	12	9.96	0.61984
22	12	11.61	0.47754
23	12	10.89	0.53821
24	12	6.33	0.89832
25	12	19.63	0.07435
26	12	8.08	0.77875
27	12	11.94	0.45012
28	12	14.81	0.25185
29	12	16.27	0.17913
30	12	6.74	0.87401
31	12	7.47	0.82485
32	12	11.71	0.46896
33	12	11.46	0.49030
34	12	3.71	0.98807
35	12	13.55	0.33043
36	12	9.94	0.62144
37	12	8.99	0.70368
38	12	10.79	0.54719
39	12	7.27	0.83909
40	12	12.59	0.39956
41	12	5.44	0.94177
42	12	8.17	0.77174
43	12	8.92	0.70966
44	12	6.83	0.86860
45	12	6.05	0.91378
46	12	3.93	0.98473
47	12	9.71	0.64104
48	12	11.31	0.50274
49	12	8.67	0.73115
50	12	12.32	0.42060
51	12	8.49	0.74581
52	12	7.79	0.80152
53	12	15.37	0.22174
54	12	12.82	0.38199
55	12	12.15	0.43369
56	12	10.86	0.54068
57	12	14.10	0.29452
58	12	7.60	0.81593
59	12	4.37	0.97583
60	12	7.70	0.80780
61	12	11.92	0.45243
62	12	9.94	0.62121
63	12	15.18	0.23164
64	12	8.74	0.72483
65	12	12.43	0.41212
66	12	7.62	0.81400
67	12	8.68	0.73028
68	12	11.19	0.51308
69	12	16.72	0.16060
70	12	8.39	0.75433

71	12	16.67	0.16248
72	12	13.09	0.36281
73	12	11.76	0.46513
74	12	21.40	0.04488
75	12	27.12	0.00743
76	12	9.57	0.65377
77	12	16.49	0.16972
78	12	9.95	0.62029
79	12	15.46	0.21711
80	12	17.85	0.12018
81	12	11.08	0.52216
82	12	17.31	0.13835
83	12	10.33	0.58679
84	12	10.41	0.58042
85	12	17.03	0.14865
86	12	8.22	0.76779
87	12	10.81	0.54494
88	12	3.51	0.99071
89	12	4.61	0.96975
90	12	11.13	0.51751
91	12	10.40	0.58133
92	12	15.43	0.21882
93	12	8.90	0.71143
94	12	10.33	0.58679
95	12	10.90	0.53765
96	12	10.71	0.55398
97	12	11.61	0.47750
98	12	8.27	0.76331
99	12	16.26	0.17966
100	12	11.51	0.48553
Combined P-value for all tests (Using KS method)			0.06188

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)	0.05691	0.28457
Opening Score (Dealer)	0.88354	1.00000
Dealer's Final Score	0.87912	1.00000
Player Cards Rank	0.84066	1.00000
Dealer Cards Rank	0.06188	0.28457
Combined P-Value using Holm's Method		0.28457

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.

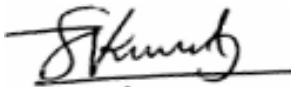
We conclude that the Random Number Generator (RNG) is working correctly.

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:



Gyulserian Hyussein
Senior Consultant
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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.