



Blackjack Cards Analysis – February 2021

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **February 01, 2021 to February 28, 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	17.92	0.39419
2	17	22.07	0.18205
3	17	5.22	0.99706
4	17	11.19	0.84652
5	17	17.50	0.42092
6	17	14.41	0.63799
7	17	24.80	0.09929
8	17	13.83	0.67913
9	17	13.06	0.73242
10	17	15.93	0.52911
11	17	29.22	0.03259
12	17	14.15	0.65635
13	17	9.20	0.93366
14	17	11.29	0.84095
15	17	24.46	0.10746
16	17	17.99	0.38939
17	17	29.20	0.03269
18	17	7.79	0.97087
19	17	24.27	0.11225
20	17	13.81	0.68015
21	17	14.57	0.62678
22	17	15.41	0.56592
23	17	27.56	0.05035

24	17	12.89	0.74377
25	17	21.18	0.21815
26	17	30.20	0.02491
27	17	18.20	0.37621
28	17	17.02	0.45334
29	17	15.69	0.54560
30	17	8.75	0.94771
31	17	14.99	0.59650
32	17	10.29	0.89111
33	17	26.12	0.07236
34	17	13.74	0.68554
35	17	17.01	0.45347
36	17	22.40	0.16969
37	17	20.80	0.23523
38	17	12.25	0.78501
39	17	25.79	0.07846
40	17	16.69	0.47561
41	17	27.80	0.04735
42	17	15.36	0.56979
43	17	17.20	0.44101
44	17	18.92	0.33290
45	17	10.70	0.87168
46	17	11.77	0.81361
47	17	12.84	0.74703
48	17	11.42	0.83416
49	17	13.37	0.71122
50	17	11.68	0.81897
51	17	7.31	0.97913
52	17	15.94	0.52778
53	17	13.23	0.72050
54	17	9.32	0.92954
55	17	27.75	0.04797
56	17	14.36	0.64134
57	17	5.58	0.99559
58	17	14.14	0.65715
59	17	15.53	0.55718
60	17	9.08	0.93774
61	17	20.69	0.24042
62	17	19.06	0.32535
63	17	7.57	0.97493
64	17	14.22	0.65174
65	17	13.76	0.68403
66	17	12.87	0.74493
67	17	18.69	0.34636
68	17	11.10	0.85128
69	17	25.29	0.08834
70	17	15.55	0.55582
71	17	15.97	0.52573
72	17	24.01	0.11904
73	17	11.24	0.84373
74	17	5.73	0.99485
75	17	13.27	0.71822
76	17	7.03	0.98319
77	17	16.65	0.47812
78	17	6.33	0.99069

79	17	19.48	0.30147
80	17	21.22	0.21663
81	17	23.82	0.12437
82	17	9.43	0.92596
83	17	15.15	0.58498
84	17	6.50	0.98911
85	17	16.14	0.51424
86	17	15.65	0.54886
87	17	15.39	0.56730
88	17	16.18	0.51083
89	17	11.81	0.81167
90	17	19.29	0.31194
91	17	28.31	0.04142
92	17	12.58	0.76368
93	17	26.75	0.06177
94	17	12.75	0.75298
95	17	13.55	0.69862
96	17	23.34	0.13865
97	17	16.43	0.49371
98	17	19.35	0.30870
99	17	21.33	0.21196
100	17	15.63	0.55032
Combined P-value for all tests (Using KS method)			0.16058

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	28.30	0.04159
2	17	15.97	0.52617
3	17	14.34	0.64300
4	17	10.78	0.86752
5	17	17.67	0.40978
6	17	23.44	0.13536
7	17	23.33	0.13874
8	17	12.04	0.79755
9	17	8.93	0.94256
10	17	10.17	0.89639
11	17	12.86	0.74545
12	17	20.74	0.23795
13	17	10.10	0.89955
14	17	9.98	0.90440
15	17	22.67	0.16047
16	17	16.20	0.50943
17	17	17.76	0.40422
18	17	13.52	0.70043
19	17	17.99	0.38969
20	17	15.93	0.52869
21	17	17.91	0.39461
22	17	20.03	0.27250
23	17	27.48	0.05135

24	17	9.42	0.92599
25	17	8.71	0.94903
26	17	11.57	0.82555
27	17	10.52	0.88044
28	17	18.22	0.37534
29	17	23.31	0.13957
30	17	13.03	0.73440
31	17	15.59	0.55340
32	17	14.37	0.64047
33	17	18.15	0.37913
34	17	17.89	0.39585
35	17	18.31	0.36967
36	17	29.25	0.03227
37	17	14.49	0.63221
38	17	11.61	0.82305
39	17	24.71	0.10131
40	17	19.93	0.27803
41	17	17.89	0.39590
42	17	36.77	0.00361
43	17	15.11	0.58769
44	17	15.06	0.59099
45	17	13.53	0.70034
46	17	9.74	0.91411
47	17	9.51	0.92307
48	17	18.61	0.35142
49	17	18.74	0.34364
50	17	15.78	0.53927
51	17	40.05	0.00127
52	17	9.74	0.91430
53	17	25.19	0.09044
54	17	20.68	0.24108
55	17	16.35	0.49886
56	17	26.24	0.07017
57	17	15.85	0.53460
58	17	20.19	0.26467
59	17	6.73	0.98678
60	17	14.11	0.65898
61	17	16.49	0.48938
62	17	12.98	0.73750
63	17	11.58	0.82460
64	17	19.67	0.29129
65	17	12.50	0.76927
66	17	28.26	0.04196
67	17	17.14	0.44523
68	17	10.53	0.88007
69	17	19.68	0.29096
70	17	17.16	0.44350
71	17	21.78	0.19316
72	17	20.80	0.23528
73	17	31.69	0.01643
74	17	14.72	0.61563
75	17	12.76	0.75233
76	17	11.28	0.84174
77	17	19.93	0.27802
78	17	13.02	0.73462

79	17	7.22	0.98055
80	17	16.43	0.49371
81	17	14.31	0.64495
82	17	15.29	0.57426
83	17	22.60	0.16261
84	17	17.44	0.42489
85	17	12.60	0.76283
86	17	12.06	0.79666
87	17	22.54	0.16495
88	17	20.78	0.23637
89	17	27.92	0.04587
90	17	24.04	0.11847
91	17	13.11	0.72890
92	17	22.68	0.16011
93	17	13.47	0.70402
94	17	18.46	0.36038
95	17	17.11	0.44673
96	17	11.27	0.84223
97	17	16.14	0.51361
98	17	19.26	0.31386
99	17	16.75	0.47122
100	17	24.90	0.09703
Combined P-value for all tests (Using KS method)			0.99998

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	41.15	0.80937
2	50	49.22	0.50449
3	50	51.76	0.40512
4	50	55.83	0.26518
5	50	63.43	0.09606
6	50	45.55	0.65253
7	50	41.23	0.80693
8	50	39.86	0.84712
9	50	47.67	0.56750
10	50	44.97	0.67484
11	50	59.59	0.16610
12	50	47.71	0.56566
13	50	43.00	0.74804
14	50	55.47	0.27620
15	50	62.77	0.10604
16	50	57.16	0.22662
17	50	51.68	0.40817
18	50	39.80	0.84878
19	50	56.21	0.25374
20	50	55.04	0.28982
21	50	58.63	0.18839
22	50	41.97	0.78327
23	50	46.48	0.61553

24	50	63.78	0.09119
25	50	29.19	0.99182
26	50	51.26	0.42408
27	50	47.22	0.58542
28	50	54.11	0.32036
29	50	46.15	0.62858
30	50	50.25	0.46340
31	50	40.80	0.82018
32	50	43.03	0.74680
33	50	54.24	0.31617
34	50	49.64	0.48779
35	50	52.74	0.36863
36	50	51.90	0.39966
37	50	53.22	0.35148
38	50	54.15	0.31920
39	50	43.20	0.74073
40	50	68.05	0.04558
41	50	41.58	0.79590
42	50	56.34	0.24968
43	50	42.43	0.76775
44	50	46.93	0.59727
45	50	50.92	0.43733
46	50	51.38	0.41942
47	50	40.07	0.84124
48	50	42.75	0.75661
49	50	75.09	0.01237
50	50	35.60	0.93802
51	50	57.06	0.22940
52	50	46.95	0.59663
53	50	45.18	0.66672
54	50	52.69	0.37050
55	50	58.17	0.19995
56	50	46.46	0.61618
57	50	37.28	0.90852
58	50	39.34	0.86096
59	50	56.67	0.24025
60	50	47.34	0.58083
61	50	59.17	0.17575
62	50	53.32	0.34766
63	50	51.46	0.41640
64	50	31.71	0.97967
65	50	43.14	0.74308
66	50	66.12	0.06293
67	50	56.00	0.25997
68	50	49.82	0.48043
69	50	56.60	0.24239
70	50	43.93	0.71443
71	50	47.13	0.58922
72	50	69.01	0.03860
73	50	59.11	0.17705
74	50	53.38	0.34577
75	50	43.25	0.73903
76	50	42.32	0.77133
77	50	42.72	0.75789
78	50	51.37	0.42001

79	50	39.54	0.85577
80	50	54.75	0.29900
81	50	41.73	0.79088
82	50	53.55	0.33959
83	50	52.15	0.39045
84	50	50.21	0.46491
85	50	55.96	0.26121
86	50	65.47	0.06987
87	50	54.25	0.31585
88	50	59.69	0.16385
89	50	49.37	0.49850
90	50	50.69	0.44630
91	50	62.05	0.11793
92	50	44.71	0.68478
93	50	59.97	0.15792
94	50	44.27	0.70165
95	50	59.26	0.17355
96	50	30.22	0.98788
97	50	39.39	0.85973
98	50	41.22	0.80723
99	50	47.58	0.57089
100	50	70.02	0.03228
Combined P-value for all tests			0.54289

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	8.84	0.71644
2	12	20.79	0.05355
3	12	9.37	0.67106
4	12	7.34	0.83423
5	12	9.23	0.68357
6	12	14.85	0.24990
7	12	8.31	0.76050
8	12	14.74	0.25579
9	12	16.59	0.16572
10	12	11.98	0.44695
11	12	7.25	0.84091
12	12	9.68	0.64360
13	12	10.61	0.56218
14	12	16.76	0.15887
15	12	19.87	0.06951

16	12	13.06	0.36477
17	12	17.80	0.12182
18	12	7.13	0.84904
19	12	15.87	0.19741
20	12	9.16	0.68881
21	12	21.29	0.04634
22	12	11.45	0.49106
23	12	10.83	0.54391
24	12	10.32	0.58814
25	12	7.92	0.79161
26	12	14.05	0.29772
27	12	12.43	0.41164
28	12	5.65	0.93274
29	12	16.23	0.18102
30	12	10.16	0.60206
31	12	8.12	0.77600
32	12	5.32	0.94633
33	12	6.09	0.91143
34	12	10.21	0.59725
35	12	14.53	0.26819
36	12	6.01	0.91543
37	12	10.66	0.55791
38	12	27.17	0.00731
39	12	13.29	0.34812
40	12	11.66	0.47306
41	12	6.70	0.87676
42	12	8.60	0.73679
43	12	3.51	0.99070
44	12	13.32	0.34609
45	12	15.18	0.23162
46	12	9.05	0.69898
47	12	10.92	0.53594
48	12	9.76	0.63677
49	12	8.60	0.73631
50	12	6.52	0.88756
51	12	10.71	0.55415
52	12	5.96	0.91790
53	12	3.89	0.98530
54	12	10.52	0.57023
55	12	7.73	0.80551
56	12	6.48	0.89027
57	12	15.71	0.20470
58	12	15.60	0.21034
59	12	15.87	0.19741
60	12	26.77	0.00833
61	12	13.24	0.35178
62	12	10.40	0.58056
63	12	7.54	0.81989
64	12	12.40	0.41387
65	12	8.88	0.71297
66	12	14.29	0.28273
67	12	9.69	0.64331
68	12	11.40	0.49465
69	12	7.00	0.85764
70	12	19.18	0.08432

71	12	16.13	0.18532
72	12	10.85	0.54202
73	12	8.72	0.72701
74	12	11.87	0.45601
75	12	9.65	0.64672
76	12	5.67	0.93163
77	12	13.95	0.30362
78	12	14.53	0.26804
79	12	14.79	0.25302
80	12	10.07	0.60980
81	12	10.17	0.60068
82	12	5.22	0.95008
83	12	3.10	0.99478
84	12	3.85	0.98598
85	12	19.89	0.06924
86	12	11.42	0.49356
87	12	9.25	0.68134
88	12	14.98	0.24230
89	12	9.31	0.67594
90	12	14.57	0.26575
91	12	8.34	0.75814
92	12	9.93	0.62189
93	12	16.68	0.16216
94	12	8.16	0.77278
95	12	15.96	0.19287
96	12	7.92	0.79135
97	12	12.91	0.37528
98	12	16.99	0.14992
99	12	18.73	0.09517
100	12	11.54	0.48304
Combined P-value for all tests (Using KS method)			0.43449

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	9.56	0.65467
2	12	5.54	0.93730
3	12	12.78	0.38538
4	12	19.88	0.06939
5	12	12.77	0.38628
6	12	15.37	0.22162
7	12	7.76	0.80359
8	12	14.18	0.28961
9	12	10.39	0.58214
10	12	12.58	0.40029
11	12	5.64	0.93331
12	12	8.92	0.70975
13	12	11.60	0.47831
14	12	2.21	0.99901
15	12	8.50	0.74494

16	12	22.63	0.03106
17	12	19.59	0.07517
18	12	15.00	0.24166
19	12	18.55	0.10004
20	12	7.19	0.84494
21	12	3.48	0.99108
22	12	13.63	0.32496
23	12	32.73	0.00106
24	12	18.46	0.10242
25	12	10.19	0.59895
26	12	6.97	0.85946
27	12	11.55	0.48246
28	12	22.48	0.03252
29	12	7.06	0.85336
30	12	5.18	0.95162
31	12	7.20	0.84412
32	12	9.20	0.68593
33	12	3.90	0.98517
34	12	19.46	0.07806
35	12	11.87	0.45650
36	12	20.53	0.05773
37	12	12.30	0.42221
38	12	15.27	0.22700
39	12	8.59	0.73749
40	12	8.98	0.70481
41	12	9.87	0.62736
42	12	9.61	0.65048
43	12	14.69	0.25860
44	12	12.99	0.36962
45	12	7.59	0.81644
46	12	16.24	0.18058
47	12	32.35	0.00122
48	12	18.19	0.11016
49	12	6.19	0.90631
50	12	10.57	0.56608
51	12	7.28	0.83857
52	12	8.81	0.71924
53	12	10.58	0.56504
54	12	6.67	0.87863
55	12	12.26	0.42503
56	12	14.35	0.27892
57	12	16.09	0.18733
58	12	6.80	0.87029
59	12	4.22	0.97905
60	12	8.04	0.78184
61	12	5.20	0.95089
62	12	4.33	0.97667
63	12	16.24	0.18066
64	12	8.44	0.74987
65	12	17.99	0.11587
66	12	14.09	0.29525
67	12	18.51	0.10106
68	12	8.15	0.77346
69	12	19.97	0.06762
70	12	10.08	0.60912

71	12	6.60	0.88312
72	12	4.18	0.97992
73	12	8.18	0.77075
74	12	12.17	0.43181
75	12	9.46	0.66304
76	12	11.90	0.45407
77	12	9.97	0.61894
78	12	12.77	0.38568
79	12	6.01	0.91548
80	12	8.27	0.76337
81	12	10.87	0.54009
82	12	12.44	0.41117
83	12	17.59	0.12865
84	12	19.77	0.07156
85	12	17.45	0.13330
86	12	8.77	0.72278
87	12	5.55	0.93713
88	12	13.53	0.33186
89	12	8.99	0.70413
90	12	26.73	0.00845
91	12	12.99	0.37006
92	12	21.01	0.05021
93	12	3.99	0.98362
94	12	8.62	0.73532
95	12	27.35	0.00688
96	12	10.48	0.57370
97	12	12.56	0.40148
98	12	13.91	0.30656
99	12	11.00	0.52918
100	12	11.47	0.48906
Combined P-value for all tests (Using KS method)			0.62554

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)	0.16058	0.80288
Opening Score (Dealer)	0.99998	1.00000
Dealer's Final Score	0.54289	1.00000
Player Cards Rank	0.43449	1.00000
Dealer Cards Rank	0.62554	1.00000
Combined P-Value using Holm's Method		0.80288

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.

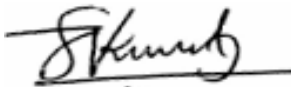
We conclude that the Random Number Generator (RNG) is working correctly.

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:



Kiren Sreekumar
Principal Consultant
iTech Labs Australia
Date: 30 April, 2021

Signed:



Gyulserian Hyussein
Senior Consultant
iTech Labs Australia
Date: 30 April, 2021

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.