

Blackjack Cards Analysis – August 2021

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **August 01, 2021 to August 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	19.63	0.29376
2	17	17.88	0.39633
3	17	25.43	0.08557
4	17	18.51	0.35751
5	17	18.00	0.38915
6	17	22.27	0.17451
7	17	15.45	0.56334
8	17	19.84	0.28264
9	17	18.43	0.36224
10	17	38.03	0.00243
11	17	16.79	0.46840
12	17	19.06	0.32516
13	17	18.38	0.36512
14	17	7.86	0.96941
15	17	20.76	0.23720
16	17	22.15	0.17884
17	17	21.76	0.19408
18	17	10.34	0.88891
19	17	20.73	0.23855
20	17	9.21	0.93330
21	17	11.63	0.82228
22	17	5.06	0.99758
23	17	11.44	0.83301

24	17	18.46	0.36043
25	17	10.17	0.89644
26	17	10.39	0.88664
27	17	26.94	0.05898
28	17	15.65	0.54882
29	17	11.09	0.85209
30	17	14.72	0.61543
31	17	9.53	0.92233
32	17	16.95	0.45782
33	17	17.75	0.40447
34	17	11.84	0.80964
35	17	9.43	0.92585
36	17	8.12	0.96383
37	17	16.72	0.47340
38	17	10.22	0.89401
39	17	13.79	0.68216
40	17	16.52	0.48697
41	17	11.87	0.80814
42	17	23.45	0.13502
43	17	17.28	0.43525
44	17	16.53	0.48663
45	17	21.72	0.19589
46	17	30.73	0.02154
47	17	13.49	0.70296
48	17	29.93	0.02689
49	17	12.93	0.74086
50	17	14.03	0.66486
51	17	16.78	0.46962
52	17	18.03	0.38708
53	17	7.49	0.97626
54	17	18.38	0.36551
55	17	14.98	0.59701
56	17	17.39	0.42828
57	17	12.92	0.74160
58	17	19.44	0.30381
59	17	21.76	0.19396
60	17	18.60	0.35196
61	17	12.49	0.76931
62	17	28.37	0.04081
63	17	18.99	0.32884
64	17	12.36	0.77806
65	17	13.40	0.70906
66	17	10.64	0.87476
67	17	26.71	0.06244
68	17	8.04	0.96565
69	17	13.53	0.70007
70	17	14.70	0.61680
71	17	19.27	0.31334
72	17	14.96	0.59833
73	17	11.46	0.83147
74	17	22.47	0.16727
75	17	10.44	0.88418
76	17	12.02	0.79895
77	17	13.66	0.69126
78	17	32.13	0.01448

79	17	19.53	0.29885
80	17	24.88	0.09748
81	17	17.56	0.41715
82	17	16.27	0.50496
83	17	14.47	0.63340
84	17	13.38	0.71065
85	17	11.81	0.81137
86	17	14.65	0.62100
87	17	12.27	0.78345
88	17	20.35	0.25683
89	17	30.43	0.02339
90	17	13.08	0.73106
91	17	8.89	0.94373
92	17	15.34	0.57131
93	17	15.29	0.57446
94	17	12.48	0.77018
95	17	12.27	0.78368
96	17	16.22	0.50814
97	17	22.66	0.16059
98	17	14.48	0.63322
99	17	16.45	0.49234
100	17	16.11	0.51589
Combined P-value for all tests (Using KS method)			0.63186

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	12.83	0.74751
2	17	12.50	0.76901
3	17	29.76	0.02810
4	17	11.41	0.83473
5	17	17.65	0.41155
6	17	16.42	0.49402
7	17	14.67	0.61944
8	17	11.54	0.82721
9	17	31.54	0.01716
10	17	22.80	0.15571
11	17	21.44	0.20718
12	17	5.59	0.99557
13	17	28.28	0.04177
14	17	9.94	0.90606
15	17	21.95	0.18650
16	17	16.25	0.50586
17	17	16.29	0.50339
18	17	21.92	0.18775
19	17	15.26	0.57661
20	17	10.60	0.87660
21	17	23.86	0.12328
22	17	25.47	0.08467
23	17	12.99	0.73664

24	17	24.43	0.10822
25	17	18.14	0.38017
26	17	14.50	0.63121
27	17	16.14	0.51388
28	17	9.96	0.90537
29	17	33.89	0.00868
30	17	13.85	0.67738
31	17	8.01	0.96632
32	17	19.74	0.28767
33	17	23.07	0.14708
34	17	9.40	0.92683
35	17	17.31	0.43342
36	17	8.75	0.94769
37	17	14.91	0.60179
38	17	21.36	0.21063
39	17	18.59	0.35233
40	17	6.09	0.99260
41	17	17.54	0.41854
42	17	12.55	0.76584
43	17	15.77	0.53996
44	17	20.01	0.27384
45	17	9.86	0.90940
46	17	13.10	0.72967
47	17	10.20	0.89508
48	17	18.63	0.35045
49	17	15.05	0.59207
50	17	14.44	0.63583
51	17	26.33	0.06865
52	17	8.71	0.94897
53	17	27.12	0.05637
54	17	22.33	0.17220
55	17	26.72	0.06234
56	17	14.43	0.63673
57	17	16.42	0.49444
58	17	14.33	0.64331
59	17	21.50	0.20460
60	17	10.31	0.88997
61	17	29.12	0.03343
62	17	15.65	0.54871
63	17	27.47	0.05152
64	17	24.46	0.10742
65	17	18.32	0.36886
66	17	23.72	0.12733
67	17	13.74	0.68524
68	17	13.92	0.67260
69	17	12.37	0.77739
70	17	24.24	0.11297
71	17	14.64	0.62104
72	17	9.82	0.91084
73	17	13.11	0.72910
74	17	10.93	0.86030
75	17	8.17	0.96278
76	17	20.84	0.23338
77	17	23.31	0.13940
78	17	13.79	0.68170

79	17	13.26	0.71876
80	17	28.31	0.04150
81	17	22.76	0.15710
82	17	21.32	0.21219
83	17	18.49	0.35861
84	17	25.99	0.07463
85	17	20.89	0.23115
86	17	9.68	0.91655
87	17	22.28	0.17412
88	17	21.07	0.22336
89	17	5.79	0.99447
90	17	10.42	0.88506
91	17	15.71	0.54420
92	17	14.77	0.61198
93	17	22.75	0.15758
94	17	14.66	0.61961
95	17	10.57	0.87811
96	17	10.91	0.86124
97	17	18.14	0.37981
98	17	17.86	0.39785
99	17	14.47	0.63358
100	17	11.38	0.83613
Combined P-value for all tests (Using KS method)			0.42441

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	49.25	0.50333
2	50	56.65	0.24093
3	50	38.42	0.88362
4	50	61.87	0.12101
5	50	38.86	0.87305
6	50	37.38	0.90640
7	50	46.41	0.61840
8	50	43.35	0.73551
9	50	46.97	0.59584
10	50	36.32	0.92643
11	50	51.74	0.40587
12	50	47.65	0.56833
13	50	46.93	0.59723
14	50	57.55	0.21588
15	50	61.62	0.12542
16	50	60.58	0.14529
17	50	59.52	0.16778
18	50	53.17	0.35307
19	50	37.08	0.91237
20	50	48.14	0.54841
21	50	39.80	0.84867
22	50	48.89	0.51798
23	50	50.66	0.44717

24	50	40.60	0.82611
25	50	58.75	0.18565
26	50	54.25	0.31563
27	50	42.60	0.76182
28	50	49.68	0.48602
29	50	49.74	0.48377
30	50	51.46	0.41654
31	50	52.53	0.37637
32	50	46.38	0.61958
33	50	60.13	0.15451
34	50	77.59	0.00746
35	50	32.08	0.97714
36	50	43.51	0.72980
37	50	57.92	0.20622
38	50	55.24	0.28348
39	50	31.26	0.98254
40	50	43.34	0.73585
41	50	40.72	0.82236
42	50	65.69	0.06747
43	50	36.75	0.91867
44	50	67.21	0.05257
45	50	51.34	0.42107
46	50	50.24	0.46404
47	50	52.66	0.37149
48	50	48.21	0.54549
49	50	39.89	0.84622
50	50	44.77	0.68250
51	50	45.54	0.65259
52	50	81.25	0.00342
53	50	48.91	0.51726
54	50	53.85	0.32934
55	50	66.57	0.05845
56	50	38.96	0.87077
57	50	60.11	0.15484
58	50	55.73	0.26803
59	50	36.59	0.92156
60	50	66.90	0.05537
61	50	60.45	0.14782
62	50	43.91	0.71497
63	50	49.11	0.50897
64	50	55.45	0.27672
65	50	34.69	0.95100
66	50	50.59	0.45017
67	50	51.26	0.42423
68	50	66.97	0.05469
69	50	42.74	0.75696
70	50	41.35	0.80319
71	50	55.66	0.27022
72	50	40.71	0.82290
73	50	59.68	0.16415
74	50	46.53	0.61335
75	50	61.95	0.11960
76	50	58.08	0.20205
77	50	53.46	0.34286
78	50	37.40	0.90601

79	50	72.04	0.02230
80	50	41.20	0.80786
81	50	53.12	0.35487
82	50	52.14	0.39079
83	50	53.38	0.34575
84	50	40.88	0.81768
85	50	41.94	0.78426
86	50	36.39	0.92518
87	50	42.53	0.76415
88	50	59.25	0.17383
89	50	63.18	0.09979
90	50	46.29	0.62289
91	50	49.28	0.50217
92	50	53.19	0.35226
93	50	39.43	0.85868
94	50	35.22	0.94377
95	50	43.52	0.72934
96	50	43.83	0.71793
Combined P-value for all tests			0.88596

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	13.25	0.35146
2	12	9.78	0.63537
3	12	9.62	0.64903
4	12	11.91	0.45323
5	12	16.24	0.18069
6	12	8.21	0.76816
7	12	8.93	0.70859
8	12	6.16	0.90755
9	12	12.95	0.37295
10	12	13.88	0.30857
11	12	22.39	0.03334
12	12	4.70	0.96726
13	12	17.55	0.13011
14	12	11.11	0.51960
15	12	7.68	0.80951
16	12	10.23	0.59623
17	12	10.41	0.58030
18	12	6.85	0.86713
19	12	20.70	0.05490

20	12	8.30	0.76119
21	12	12.07	0.43999
22	12	10.22	0.59661
23	12	11.12	0.51849
24	12	14.48	0.27135
25	12	14.03	0.29909
26	12	7.90	0.79305
27	12	6.00	0.91586
28	12	9.93	0.62245
29	12	12.89	0.37677
30	12	7.24	0.84140
31	12	17.30	0.13876
32	12	9.21	0.68518
33	12	8.58	0.73846
34	12	4.64	0.96907
35	12	15.11	0.23555
36	12	4.27	0.97813
37	12	9.06	0.69785
38	12	3.60	0.98963
39	12	8.02	0.78396
40	12	9.97	0.61903
41	12	11.97	0.44798
42	12	14.42	0.27498
43	12	5.48	0.93982
44	12	16.32	0.17712
45	12	16.43	0.17213
46	12	11.66	0.47377
47	12	13.20	0.35484
48	12	10.60	0.56330
49	12	4.26	0.97832
50	12	4.19	0.97970
51	12	20.80	0.05341
52	12	9.42	0.66641
53	12	12.29	0.42286
54	12	8.53	0.74241
55	12	10.69	0.55540
56	12	12.31	0.42117
57	12	4.64	0.96895
58	12	10.36	0.58447
59	12	11.24	0.50856
60	12	5.71	0.93000
61	12	7.19	0.84469
62	12	13.38	0.34176
63	12	17.54	0.13040
64	12	6.59	0.88352
65	12	16.01	0.19078
66	12	11.76	0.46487
67	12	8.13	0.77508
68	12	8.24	0.76573
69	12	10.02	0.61409
70	12	5.68	0.93138
71	12	16.33	0.17674
72	12	9.11	0.69377
73	12	16.43	0.17231
74	12	12.96	0.37232

75	12	18.36	0.10523
76	12	8.30	0.76119
77	12	10.35	0.58523
78	12	17.70	0.12520
79	12	11.10	0.52000
80	12	7.40	0.83027
81	12	9.60	0.65101
82	12	20.17	0.06392
83	12	10.38	0.58234
84	12	5.27	0.94838
85	12	13.48	0.33504
86	12	4.65	0.96869
87	12	14.99	0.24222
88	12	8.51	0.74397
89	12	7.55	0.81953
90	12	12.64	0.39587
91	12	13.79	0.31458
92	12	11.83	0.45954
93	12	9.04	0.69927
94	12	9.74	0.63833
95	12	10.97	0.53112
96	12	12.40	0.41436
97	12	20.92	0.05149
98	12	9.21	0.68522
99	12	23.69	0.02239
100	12	6.96	0.86029
Combined P-value for all tests (Using KS method)			0.25309

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	7.31	0.83662
2	12	19.03	0.08772
3	12	17.30	0.13860
4	12	11.52	0.48525
5	12	16.80	0.15736
6	12	14.53	0.26839
7	12	10.01	0.61521
8	12	18.62	0.09818
9	12	11.86	0.45664
10	12	9.89	0.62576
11	12	11.40	0.49530
12	12	9.92	0.62291
13	12	15.73	0.20415
14	12	17.29	0.13895
15	12	8.01	0.78437
16	12	16.04	0.18924
17	12	11.14	0.51673
18	12	15.63	0.20873
19	12	5.91	0.92038

20	12	13.39	0.34167
21	12	11.29	0.50460
22	12	2.99	0.99562
23	12	5.99	0.91684
24	12	7.94	0.78943
25	12	11.04	0.52588
26	12	11.67	0.47286
27	12	6.29	0.90074
28	12	5.22	0.95018
29	12	9.31	0.67627
30	12	9.73	0.63944
31	12	12.50	0.40630
32	12	15.95	0.19337
33	12	15.74	0.20331
34	12	8.19	0.77002
35	12	5.65	0.93248
36	12	9.37	0.67106
37	12	11.05	0.52430
38	12	9.58	0.65295
39	12	9.54	0.65597
40	12	5.72	0.92948
41	12	15.77	0.20220
42	12	8.35	0.75722
43	12	16.40	0.17354
44	12	9.49	0.66026
45	12	14.58	0.26547
46	12	11.44	0.49130
47	12	18.24	0.10872
48	12	11.98	0.44695
49	12	16.74	0.15955
50	12	17.38	0.13583
51	12	21.69	0.04110
52	12	5.14	0.95302
53	12	4.03	0.98297
54	12	24.85	0.01557
55	12	8.44	0.74991
56	12	20.21	0.06318
57	12	18.59	0.09889
58	12	7.64	0.81243
59	12	8.77	0.72205
60	12	18.89	0.09111
61	12	11.23	0.50905
62	12	8.77	0.72278
63	12	11.80	0.46216
64	12	11.85	0.45816
65	12	12.15	0.43403
66	12	11.75	0.46594
67	12	15.57	0.21191
68	12	13.98	0.30214
69	12	8.56	0.74039
70	12	4.00	0.98350
71	12	14.41	0.27524
72	12	11.66	0.47354
73	12	4.55	0.97140
74	12	18.44	0.10294

75	12	7.94	0.78982
76	12	22.51	0.03217
77	12	17.00	0.14962
78	12	12.19	0.43060
79	12	11.93	0.45137
80	12	6.24	0.90344
81	12	12.42	0.41231
82	12	7.19	0.84510
83	12	13.67	0.32257
84	12	8.33	0.75862
85	12	10.38	0.58284
86	12	10.75	0.55065
87	12	14.10	0.29407
88	12	13.86	0.30998
89	12	7.18	0.84549
90	12	10.61	0.56293
91	12	25.51	0.01257
92	12	16.83	0.15592
93	12	15.10	0.23625
94	12	12.50	0.40675
95	12	2.94	0.99598
96	12	15.26	0.22751
97	12	16.53	0.16797
98	12	9.71	0.64133
99	12	6.13	0.90947
100	12	15.00	0.24122
Combined P-value for all tests (Using KS method)			0.92451

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)	0.63186	1.00000
Opening Score (Dealer)	0.42441	1.00000
Dealer's Final Score	0.88596	1.00000
Player Cards Rank	0.25309	1.00000
Dealer Cards Rank	0.92451	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.

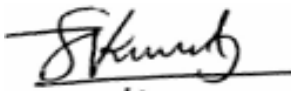
We conclude that the Random Number Generator (RNG) is working correctly.

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:



Kiren Sreekumar
Principal Consultant
iTech Labs Australia
Date: 20 September, 2021

Signed:



Gyulserian Hyussein
Senior Consultant
iTech Labs Australia
Date: 20 September, 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.

