



Blackjack Cards Analysis – June 2021

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **June 01, 2021 to June 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	16.08	0.51802
2	17	19.54	0.29830
3	17	23.65	0.12923
4	17	24.36	0.11010
5	17	15.51	0.55858
6	17	23.39	0.13684
7	17	20.42	0.25331
8	17	13.67	0.69026
9	17	12.91	0.74224
10	17	11.82	0.81081
11	17	14.03	0.66473
12	17	15.11	0.58758
13	17	34.67	0.00687
14	17	22.04	0.18313
15	17	19.24	0.31479
16	17	21.59	0.20081
17	17	22.55	0.16445
18	17	19.26	0.31398
19	17	18.42	0.36254
20	17	18.94	0.33173
21	17	18.90	0.33417
22	17	14.63	0.62208
23	17	17.94	0.39249

24	17	17.42	0.42638
25	17	19.12	0.32144
26	17	17.28	0.43579
27	17	24.65	0.10289
28	17	23.75	0.12637
29	17	9.45	0.92511
30	17	11.12	0.85005
31	17	15.39	0.56748
32	17	8.76	0.94758
33	17	13.68	0.68954
34	17	23.87	0.12291
35	17	19.02	0.32711
36	17	8.74	0.94808
37	17	7.73	0.97205
38	17	9.24	0.93259
39	17	11.16	0.84820
40	17	18.88	0.33540
41	17	23.40	0.13677
42	17	21.74	0.19512
43	17	9.36	0.92831
44	17	6.36	0.99045
45	17	25.11	0.09226
46	17	18.91	0.33369
47	17	13.00	0.73611
48	17	18.58	0.35312
49	17	16.49	0.48969
50	17	9.20	0.93380
51	17	28.39	0.04061
52	17	24.38	0.10947
53	17	11.32	0.83940
54	17	21.33	0.21185
55	17	18.19	0.37715
56	17	14.22	0.65156
57	17	15.24	0.57828
58	17	10.98	0.85772
59	17	18.85	0.33734
60	17	16.62	0.48066
61	17	29.96	0.02661
62	17	28.41	0.04039
63	17	11.81	0.81151
64	17	16.59	0.48268
65	17	23.48	0.13428
66	17	18.37	0.36592
67	17	13.17	0.72480
68	17	12.52	0.76793
69	17	12.42	0.77430
70	17	16.54	0.48567
71	17	11.10	0.85116
72	17	20.66	0.24183
73	17	14.33	0.64374
74	17	17.01	0.45378
75	17	10.09	0.89988
76	17	12.51	0.76807
77	17	21.63	0.19941
78	17	9.30	0.93041

79	17	12.44	0.77296
80	17	16.70	0.47495
81	17	23.52	0.13305
82	17	18.23	0.37417
83	17	15.53	0.55712
84	17	10.18	0.89586
85	17	18.12	0.38129
86	17	10.78	0.86765
87	17	13.41	0.70832
88	17	9.74	0.91425
89	17	11.94	0.80384
90	17	19.61	0.29455
91	17	6.73	0.98676
92	17	16.23	0.50748
93	17	19.17	0.31899
94	17	23.12	0.14533
95	17	11.21	0.84518
96	17	6.51	0.98903
97	17	6.63	0.98781
98	17	17.14	0.44481
99	17	12.23	0.78623
100	17	14.43	0.63635
Combined P-value for all tests (Using KS method)			0.73075

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	14.74	0.61388
2	17	13.87	0.67639
3	17	22.05	0.18299
4	17	12.27	0.78328
5	17	13.19	0.72309
6	17	17.87	0.39713
7	17	14.48	0.63299
8	17	20.83	0.23395
9	17	21.19	0.21780
10	17	21.57	0.20190
11	17	21.18	0.21849
12	17	21.54	0.20287
13	17	11.80	0.81221
14	17	12.34	0.77931
15	17	23.59	0.13088
16	17	10.61	0.87591
17	17	18.66	0.34855
18	17	18.81	0.33973
19	17	17.23	0.43909
20	17	13.34	0.71281
21	17	23.93	0.12122
22	17	11.07	0.85297
23	17	12.08	0.79503

24	17	19.83	0.28276
25	17	8.30	0.95978
26	17	15.06	0.59098
27	17	11.95	0.80288
28	17	17.62	0.41291
29	17	18.40	0.36414
30	17	12.10	0.79409
31	17	15.30	0.57355
32	17	21.85	0.19075
33	17	11.83	0.81006
34	17	8.15	0.96333
35	17	15.54	0.55629
36	17	9.58	0.92013
37	17	15.89	0.53140
38	17	20.26	0.26117
39	17	13.29	0.71690
40	17	28.97	0.03477
41	17	24.80	0.09928
42	17	20.48	0.25038
43	17	6.14	0.99221
44	17	19.76	0.28689
45	17	33.24	0.01052
46	17	10.98	0.85756
47	17	19.27	0.31349
48	17	11.63	0.82220
49	17	18.11	0.38186
50	17	8.91	0.94307
51	17	13.79	0.68214
52	17	7.99	0.96679
53	17	31.82	0.01583
54	17	15.47	0.56184
55	17	12.41	0.77475
56	17	13.45	0.70544
57	17	10.67	0.87336
58	17	15.40	0.56672
59	17	15.75	0.54159
60	17	17.80	0.40168
61	17	15.24	0.57822
62	17	19.16	0.31936
63	17	12.54	0.76611
64	17	7.50	0.97602
65	17	16.79	0.46899
66	17	8.33	0.95908
67	17	30.50	0.02295
68	17	13.28	0.71730
69	17	17.65	0.41114
70	17	10.69	0.87236
71	17	22.00	0.18471
72	17	30.70	0.02169
73	17	10.98	0.85766
74	17	17.18	0.44219
75	17	13.62	0.69358
76	17	20.15	0.26665
77	17	14.83	0.60797
78	17	13.00	0.73649

79	17	16.32	0.50114
80	17	20.31	0.25879
81	17	12.12	0.79286
82	17	29.52	0.03005
83	17	11.32	0.83935
84	17	15.35	0.57059
85	17	23.27	0.14076
86	17	21.64	0.19906
87	17	23.21	0.14267
88	17	19.13	0.32085
89	17	11.80	0.81228
90	17	17.07	0.44944
91	17	21.09	0.22213
92	17	14.06	0.66291
93	17	16.95	0.45794
94	17	32.16	0.01436
95	17	11.40	0.83510
96	17	8.19	0.96226
97	17	13.94	0.67121
98	17	24.82	0.09883
99	17	14.25	0.64941
100	17	16.03	0.52140
Combined P-value for all tests (Using KS method)			0.75783

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	64.96	0.07585
2	50	78.26	0.00649
3	50	58.85	0.18322
4	50	47.28	0.58337
5	50	46.59	0.61088
6	50	48.19	0.54636
7	50	69.96	0.03261
8	50	29.08	0.99216
9	50	36.31	0.92647
10	50	58.50	0.19152
11	50	35.53	0.93913
12	50	50.87	0.43901
13	50	36.18	0.92878
14	50	43.92	0.71466
15	50	54.88	0.29473
16	50	55.81	0.26577
17	50	53.69	0.33498
18	50	27.77	0.99546
19	50	45.45	0.65628
20	50	43.21	0.74063
21	50	59.05	0.17851
22	50	35.36	0.94166
23	50	64.26	0.08466

24	50	46.56	0.61217
25	50	46.52	0.61374
26	50	51.17	0.42758
27	50	48.38	0.53849
28	50	59.58	0.16629
29	50	39.08	0.86761
30	50	35.37	0.94158
31	50	47.64	0.56865
32	50	49.06	0.51102
33	50	46.15	0.62844
34	50	56.08	0.25736
35	50	46.57	0.61162
36	50	53.46	0.34269
37	50	43.08	0.74528
38	50	37.36	0.90674
39	50	36.53	0.92262
40	50	61.04	0.13616
41	50	71.43	0.02496
42	50	64.06	0.08731
43	50	48.21	0.54535
44	50	52.22	0.38783
45	50	54.16	0.31856
46	50	57.47	0.21799
47	50	46.21	0.62637
48	50	60.30	0.15100
49	50	57.90	0.20684
50	50	71.30	0.02557
51	50	58.63	0.18850
52	50	57.19	0.22575
53	50	72.48	0.02050
54	50	34.47	0.95381
55	50	50.92	0.43707
56	50	52.46	0.37898
57	50	68.56	0.04177
58	50	44.70	0.68525
59	50	53.42	0.34419
60	50	44.83	0.68052
61	50	39.98	0.84378
62	50	35.92	0.93312
63	50	65.22	0.07277
64	50	55.41	0.27792
65	50	37.35	0.90703
66	50	47.53	0.57287
67	50	53.79	0.33144
68	50	30.17	0.98811
69	50	46.47	0.61592
70	50	52.57	0.37486
71	50	47.30	0.58218
72	50	37.21	0.90988
73	50	44.47	0.69392
74	50	56.59	0.24261
75	50	52.78	0.36726
76	50	49.91	0.47698
77	50	59.47	0.16878
78	50	40.24	0.83651

79	50	49.49	0.49396
80	50	53.09	0.35612
81	50	34.02	0.95912
82	50	47.89	0.55828
83	50	51.73	0.40597
84	50	41.76	0.79011
85	50	36.94	0.91511
86	50	39.31	0.86173
87	50	46.49	0.61487
88	50	41.07	0.81196
89	50	47.38	0.57914
90	50	55.08	0.28834
91	50	54.31	0.31370
92	50	40.25	0.83620
93	50	64.50	0.08152
94	50	57.77	0.21004
95	50	62.00	0.11885
96	50	55.29	0.28181
97	50	57.36	0.22096
98	50	79.38	0.00512
99	50	75.06	0.01245
100	50	53.95	0.32595
Combined P-value for all tests			0.75045

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	11.44	0.49176
2	12	17.08	0.14671
3	12	19.49	0.07740
4	12	8.77	0.72242
5	12	7.96	0.78792
6	12	14.78	0.25390
7	12	8.42	0.75157
8	12	11.06	0.52366
9	12	11.42	0.49366
10	12	9.59	0.65223
11	12	10.99	0.53005
12	12	6.44	0.89211
13	12	17.09	0.14635
14	12	7.88	0.79471
15	12	12.75	0.38712

16	12	8.65	0.73250
17	12	14.96	0.24373
18	12	10.54	0.56885
19	12	12.60	0.39862
20	12	9.54	0.65592
21	12	15.61	0.20953
22	12	11.83	0.45928
23	12	13.40	0.34100
24	12	15.56	0.21209
25	12	11.98	0.44745
26	12	21.10	0.04897
27	12	12.87	0.37891
28	12	19.52	0.07677
29	12	9.13	0.69198
30	12	13.90	0.30722
31	12	8.63	0.73385
32	12	8.62	0.73467
33	12	3.06	0.99508
34	12	9.84	0.63032
35	12	16.17	0.18370
36	12	10.39	0.58218
37	12	15.56	0.21225
38	12	11.17	0.51451
39	12	9.90	0.62434
40	12	9.60	0.65138
41	12	5.22	0.95018
42	12	21.07	0.04934
43	12	10.73	0.55247
44	12	9.97	0.61892
45	12	7.04	0.85466
46	12	13.23	0.35283
47	12	12.08	0.43964
48	12	18.31	0.10672
49	12	16.97	0.15073
50	12	14.16	0.29048
51	12	26.22	0.00999
52	12	11.04	0.52532
53	12	14.87	0.24845
54	12	8.13	0.77508
55	12	9.36	0.67207
56	12	15.13	0.23439
57	12	10.57	0.56595
58	12	12.29	0.42287
59	12	26.39	0.00946
60	12	19.41	0.07907
61	12	7.90	0.79272
62	12	7.58	0.81692
63	12	15.56	0.21220
64	12	11.14	0.51715
65	12	9.91	0.62386
66	12	23.67	0.02257
67	12	8.44	0.74967
68	12	14.88	0.24813
69	12	13.12	0.36041
70	12	14.58	0.26513

71	12	11.82	0.46004
72	12	14.14	0.29190
73	12	7.57	0.81755
74	12	9.12	0.69278
75	12	8.07	0.77965
76	12	12.36	0.41746
77	12	21.15	0.04818
78	12	19.10	0.08609
79	12	16.45	0.17146
80	12	9.69	0.64335
81	12	17.53	0.13079
82	12	6.34	0.89802
83	12	15.27	0.22721
84	12	14.60	0.26395
85	12	21.25	0.04677
86	12	9.03	0.69997
87	12	12.23	0.42718
88	12	17.83	0.12091
89	12	9.67	0.64461
90	12	12.74	0.38857
91	12	17.75	0.12339
92	12	9.94	0.62132
93	12	11.80	0.46169
94	12	6.61	0.88257
95	12	7.77	0.80311
96	12	3.79	0.98700
97	12	13.59	0.32782
98	12	13.24	0.35219
99	12	12.94	0.37317
100	12	18.21	0.10937
Combined P-value for all tests (Using KS method)			0.23159

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	12.59	0.39948
2	12	9.70	0.64185
3	12	12.94	0.37355
4	12	11.79	0.46235
5	12	11.73	0.46738
6	12	14.65	0.26131
7	12	10.67	0.55706
8	12	4.03	0.98281
9	12	10.15	0.60268
10	12	19.66	0.07384
11	12	6.37	0.89605
12	12	6.87	0.86588
13	12	7.08	0.85205
14	12	10.09	0.60786
15	12	10.81	0.54519

16	12	10.57	0.56631
17	12	14.98	0.24238
18	12	14.75	0.25542
19	12	9.82	0.63134
20	12	4.61	0.96965
21	12	7.78	0.80196
22	12	10.19	0.59960
23	12	11.03	0.52641
24	12	8.17	0.77176
25	12	10.32	0.58765
26	12	16.64	0.16361
27	12	5.14	0.95305
28	12	15.77	0.20210
29	12	9.69	0.64330
30	12	6.14	0.90902
31	12	8.20	0.76951
32	12	5.76	0.92789
33	12	14.28	0.28349
34	12	10.10	0.60701
35	12	18.21	0.10953
36	12	14.29	0.28243
37	12	6.59	0.88375
38	12	9.74	0.63912
39	12	12.14	0.43426
40	12	10.57	0.56608
41	12	14.62	0.26291
42	12	7.47	0.82509
43	12	7.83	0.79800
44	12	18.28	0.10754
45	12	25.63	0.01209
46	12	15.42	0.21921
47	12	13.95	0.30391
48	12	5.46	0.94079
49	12	12.93	0.37403
50	12	6.72	0.87529
51	12	8.25	0.76569
52	12	6.56	0.88530
53	12	12.95	0.37244
54	12	5.23	0.94980
55	12	8.16	0.77228
56	12	5.61	0.93434
57	12	22.88	0.02873
58	12	9.71	0.64102
59	12	20.17	0.06397
60	12	6.01	0.91573
61	12	18.11	0.11239
62	12	4.54	0.97166
63	12	10.18	0.60017
64	12	18.04	0.11453
65	12	8.40	0.75305
66	12	9.00	0.70319
67	12	17.03	0.14852
68	12	4.74	0.96618
69	12	13.55	0.33057
70	12	3.16	0.99429

71	12	6.76	0.87286
72	12	6.58	0.88427
73	12	8.86	0.71480
74	12	9.24	0.68215
75	12	8.09	0.77778
76	12	7.92	0.79167
77	12	18.17	0.11073
78	12	19.45	0.07816
79	12	8.62	0.73500
80	12	19.28	0.08209
81	12	16.09	0.18731
82	12	15.59	0.21052
83	12	9.73	0.63988
84	12	14.21	0.28750
85	12	7.93	0.79033
86	12	10.25	0.59410
87	12	11.03	0.52622
88	12	15.53	0.21375
89	12	12.01	0.44481
90	12	12.34	0.41910
91	12	15.02	0.24056
92	12	5.70	0.93028
93	12	14.55	0.26722
94	12	22.01	0.03741
95	12	7.01	0.85708
96	12	8.35	0.75728
97	12	11.06	0.52418
98	12	11.26	0.50686
99	12	13.69	0.32080
100	12	15.27	0.22707
Combined P-value for all tests (Using KS method)			0.21521

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)	0.73075	1.00000
Opening Score (Dealer)	0.75783	1.00000
Dealer's Final Score	0.75045	1.00000
Player Cards Rank	0.23159	1.00000
Dealer Cards Rank	0.21521	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.

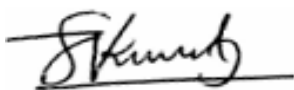
We conclude that the Random Number Generator (RNG) is working correctly.

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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Date: 28 July, 2021

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.