



Blackjack Cards Analysis – April 2021

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **April 01, 2021 to April 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	25.81	0.07798
2	17	12.73	0.75406
3	17	22.07	0.18189
4	17	20.39	0.25501
5	17	25.81	0.07794
6	17	20.76	0.23722
7	17	28.76	0.03681
8	17	21.78	0.19320
9	17	19.17	0.31892
10	17	18.36	0.36665
11	17	24.73	0.10095
12	17	16.44	0.49318
13	17	11.99	0.80075
14	17	9.27	0.93142
15	17	18.63	0.35029
16	17	19.97	0.27560
17	17	15.35	0.56995
18	17	10.93	0.86010
19	17	12.71	0.75562
20	17	19.16	0.31930
21	17	5.97	0.99335
22	17	14.19	0.65344
23	17	18.07	0.38461

24	17	22.27	0.17474
25	17	5.71	0.99495
26	17	16.43	0.49374
27	17	18.53	0.35587
28	17	15.23	0.57908
29	17	19.25	0.31456
30	17	7.81	0.97041
31	17	22.41	0.16956
32	17	19.98	0.27510
33	17	16.59	0.48254
34	17	13.72	0.68708
35	17	26.10	0.07266
36	17	12.25	0.78481
37	17	16.28	0.50432
38	17	14.50	0.63177
39	17	19.72	0.28855
40	17	11.35	0.83754
41	17	15.34	0.57094
42	17	25.50	0.08416
43	17	20.29	0.25955
44	17	17.58	0.41582
45	17	10.39	0.88627
46	17	14.96	0.59858
47	17	12.10	0.79408
48	17	5.98	0.99334
49	17	20.76	0.23729
50	17	20.68	0.24088
51	17	16.40	0.49586
52	17	9.49	0.92357
53	17	13.71	0.68771
54	17	15.86	0.53358
55	17	17.03	0.45250
56	17	28.10	0.04378
57	17	14.50	0.63143
58	17	17.72	0.40675
59	17	18.76	0.34263
60	17	28.14	0.04327
61	17	25.29	0.08832
62	17	10.27	0.89200
63	17	17.88	0.39641
64	17	12.35	0.77848
65	17	17.54	0.41870
66	17	29.41	0.03093
67	17	18.21	0.37569
68	17	14.31	0.64504
69	17	11.60	0.82349
70	17	14.30	0.64559
71	17	12.13	0.79246
72	17	9.21	0.93351
73	17	11.12	0.85022
74	17	27.80	0.04730
75	17	26.61	0.06403
76	17	29.33	0.03161
77	17	11.97	0.80199
78	17	15.41	0.56584

79	17	15.61	0.55149
80	17	17.77	0.40322
81	17	14.96	0.59825
82	17	14.76	0.61245
83	17	21.95	0.18680
84	17	10.13	0.89821
85	17	12.82	0.74791
86	17	15.12	0.58719
87	17	19.45	0.30316
88	17	14.54	0.62825
89	17	13.03	0.73431
90	17	13.64	0.69220
91	17	7.88	0.96903
92	17	24.35	0.11018
93	17	17.55	0.41772
94	17	15.59	0.55291
95	17	18.97	0.33040
96	17	11.73	0.81643
97	17	20.57	0.24594
98	17	12.90	0.74272
99	17	11.83	0.81051
100	17	8.23	0.96137
Combined P-value for all tests (Using KS method)			0.97614

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	16.15	0.51299
2	17	13.07	0.73123
3	17	10.04	0.90189
4	17	11.08	0.85217
5	17	21.64	0.19880
6	17	17.37	0.42970
7	17	16.83	0.46565
8	17	15.60	0.55266
9	17	19.96	0.27629
10	17	18.14	0.37988
11	17	23.04	0.14804
12	17	8.62	0.95156
13	17	19.18	0.31841
14	17	11.16	0.84817
15	17	7.67	0.97317
16	17	14.55	0.62812
17	17	13.81	0.68082
18	17	11.03	0.85491
19	17	15.69	0.54614
20	17	22.79	0.15609
21	17	12.60	0.76221
22	17	13.82	0.68010
23	17	35.56	0.00524

24	17	19.56	0.29742
25	17	10.96	0.85845
26	17	13.99	0.66754
27	17	10.71	0.87138
28	17	19.58	0.29640
29	17	21.30	0.21303
30	17	18.69	0.34685
31	17	14.89	0.60345
32	17	21.56	0.20209
33	17	32.21	0.01417
34	17	12.33	0.77956
35	17	19.27	0.31318
36	17	31.80	0.01594
37	17	22.70	0.15931
38	17	21.37	0.21012
39	17	13.78	0.68275
40	17	19.27	0.31352
41	17	19.65	0.29228
42	17	9.58	0.92019
43	17	22.98	0.14982
44	17	15.35	0.57017
45	17	15.20	0.58087
46	17	19.72	0.28895
47	17	24.19	0.11429
48	17	12.48	0.77038
49	17	16.12	0.51536
50	17	16.71	0.47443
51	17	11.25	0.84302
52	17	16.87	0.46288
53	17	29.94	0.02677
54	17	7.44	0.97716
55	17	15.49	0.56010
56	17	16.79	0.46834
57	17	16.47	0.49088
58	17	20.02	0.27315
59	17	22.97	0.15008
60	17	10.79	0.86741
61	17	7.47	0.97654
62	17	25.85	0.07730
63	17	11.16	0.84806
64	17	13.87	0.67641
65	17	21.81	0.19232
66	17	13.61	0.69421
67	17	18.35	0.36714
68	17	18.98	0.32974
69	17	20.05	0.27159
70	17	21.07	0.22297
71	17	17.74	0.40532
72	17	11.92	0.80486
73	17	20.99	0.22680
74	17	17.01	0.45379
75	17	11.87	0.80792
76	17	15.32	0.57229
77	17	17.81	0.40075
78	17	14.21	0.65234

79	17	10.62	0.87548
80	17	14.03	0.66498
81	17	24.16	0.11515
82	17	32.61	0.01263
83	17	15.28	0.57509
84	17	15.08	0.58946
85	17	10.35	0.88840
86	17	16.66	0.47743
87	17	13.40	0.70898
88	17	21.13	0.22035
89	17	14.11	0.65964
90	17	11.78	0.81304
91	17	17.24	0.43850
92	17	19.48	0.30170
93	17	15.59	0.55320
94	17	15.58	0.55352
95	17	13.31	0.71513
96	17	11.39	0.83564
97	17	11.53	0.82801
98	17	18.25	0.37297
99	17	7.72	0.97218
100	17	12.73	0.75427
Combined P-value for all tests (Using KS method)			0.72900

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	37.39	0.90624
2	50	50.86	0.43972
3	50	34.47	0.95374
4	50	60.52	0.14646
5	50	43.82	0.71832
6	50	55.15	0.28620
7	50	54.51	0.30700
8	50	50.55	0.45180
9	50	61.17	0.13381
10	50	46.61	0.61019
11	50	56.25	0.25259
12	50	54.98	0.29161
13	50	55.37	0.27938
14	50	53.72	0.33382
15	50	68.96	0.03892
16	50	40.92	0.81648
17	50	54.89	0.29467
18	50	48.93	0.51637
19	50	31.04	0.98379
20	50	58.60	0.18925
21	50	49.74	0.48384
22	50	29.71	0.98998
23	50	48.67	0.52676

24	50	59.65	0.16479
25	50	49.10	0.50945
26	50	49.93	0.47638
27	50	41.94	0.78426
28	50	38.35	0.88534
29	50	52.89	0.36315
30	50	48.86	0.51925
31	50	32.52	0.97371
32	50	18.67	0.99998
33	50	55.10	0.28768
34	50	53.64	0.33659
35	50	43.56	0.72790
36	50	37.42	0.90554
37	50	38.64	0.87860
38	50	55.20	0.28448
39	50	74.97	0.01268
40	50	55.54	0.27381
41	50	32.27	0.97567
42	50	47.83	0.56107
43	50	31.46	0.98132
44	50	65.62	0.06820
45	50	65.67	0.06769
46	50	62.72	0.10689
47	50	56.65	0.24078
48	50	48.94	0.51583
49	50	43.55	0.72818
50	50	56.02	0.25934
51	50	49.95	0.47546
52	50	59.48	0.16870
53	50	59.13	0.17648
54	50	46.12	0.62998
55	50	55.44	0.27716
56	50	45.37	0.65961
57	50	45.31	0.66167
58	50	68.50	0.04219
59	50	57.59	0.21492
60	50	41.60	0.79504
61	50	45.27	0.66333
62	50	53.82	0.33025
63	50	42.85	0.75334
64	50	46.67	0.60762
65	50	44.64	0.68774
66	50	53.05	0.35728
67	50	41.28	0.80531
68	50	44.43	0.69553
69	50	43.15	0.74275
70	50	52.34	0.38313
71	50	62.64	0.10811
72	50	50.48	0.45440
73	50	59.88	0.15986
74	50	49.64	0.48759
75	50	56.96	0.23219
76	50	48.35	0.53964
77	50	48.25	0.54399
78	50	65.16	0.07349

79	50	60.14	0.15435
80	50	70.15	0.03150
81	50	47.43	0.57716
82	50	43.87	0.71666
83	50	33.35	0.96621
84	50	48.36	0.53952
85	50	67.78	0.04772
86	50	65.34	0.07139
87	50	63.95	0.08877
88	50	58.31	0.19623
89	50	49.58	0.49016
90	50	44.29	0.70085
91	50	75.40	0.01163
92	50	40.43	0.83088
93	50	54.19	0.31760
94	50	68.90	0.03932
95	50	70.66	0.02873
96	50	39.77	0.84963
97	50	64.18	0.08569
98	50	46.11	0.63037
99	50	55.78	0.26665
100	50	47.48	0.57512
Combined P-value for all tests			0.33197

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	12.89	0.37723
2	12	5.25	0.94908
3	12	8.32	0.75977
4	12	13.67	0.32219
5	12	4.76	0.96562
6	12	12.19	0.43060
7	12	14.05	0.29764
8	12	10.59	0.56432
9	12	27.06	0.00758
10	12	12.28	0.42370
11	12	16.74	0.15967
12	12	7.96	0.78842
13	12	8.48	0.74650
14	12	10.92	0.53620
15	12	7.69	0.80853

16	12	11.69	0.47099
17	12	5.69	0.93078
18	12	7.90	0.79320
19	12	5.84	0.92415
20	12	13.36	0.34325
21	12	5.48	0.93981
22	12	11.33	0.50049
23	12	8.65	0.73250
24	12	6.48	0.88985
25	12	18.96	0.08952
26	12	4.31	0.97714
27	12	7.55	0.81889
28	12	13.37	0.34303
29	12	10.83	0.54320
30	12	13.40	0.34055
31	12	13.95	0.30386
32	12	19.92	0.06860
33	12	14.24	0.28545
34	12	8.20	0.76893
35	12	14.57	0.26571
36	12	13.09	0.36234
37	12	21.13	0.04851
38	12	9.08	0.69617
39	12	3.98	0.98374
40	12	13.62	0.32546
41	12	12.23	0.42753
42	12	10.41	0.58048
43	12	19.41	0.07902
44	12	10.73	0.55247
45	12	11.55	0.48254
46	12	14.27	0.28385
47	12	24.38	0.01803
48	12	10.02	0.61379
49	12	10.42	0.57934
50	12	21.22	0.04728
51	12	9.34	0.67345
52	12	11.66	0.47313
53	12	12.97	0.37128
54	12	10.75	0.55022
55	12	12.58	0.40010
56	12	16.05	0.18880
57	12	7.69	0.80853
58	12	10.60	0.56319
59	12	7.28	0.83867
60	12	20.29	0.06183
61	12	5.88	0.92196
62	12	8.07	0.78003
63	12	4.61	0.96975
64	12	5.68	0.93151
65	12	12.25	0.42599
66	12	11.81	0.46087
67	12	9.03	0.70007
68	12	19.23	0.08308
69	12	11.59	0.47877
70	12	7.64	0.81289

71	12	24.80	0.01579
72	12	11.30	0.50378
73	12	9.05	0.69895
74	12	11.16	0.51562
75	12	23.41	0.02448
76	12	17.70	0.12496
77	12	9.42	0.66655
78	12	13.63	0.32490
79	12	16.44	0.17195
80	12	15.09	0.23641
81	12	6.64	0.88047
82	12	11.44	0.49202
83	12	18.32	0.10624
84	12	7.69	0.80898
85	12	8.14	0.77394
86	12	16.30	0.17787
87	12	14.73	0.25678
88	12	11.96	0.44858
89	12	10.26	0.59320
90	12	17.68	0.12572
91	12	9.29	0.67808
92	12	4.93	0.96038
93	12	10.63	0.56092
94	12	6.24	0.90329
95	12	10.30	0.58991
96	12	6.55	0.88602
97	12	7.41	0.82971
98	12	18.41	0.10366
99	12	8.95	0.70687
100	12	6.22	0.90463
Combined P-value for all tests (Using KS method)			0.79691

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	21.44	0.04429
2	12	5.33	0.94615
3	12	9.99	0.61698
4	12	6.36	0.89711
5	12	17.00	0.14964
6	12	11.99	0.44683
7	12	14.70	0.25817
8	12	13.76	0.31625
9	12	18.15	0.11135
10	12	7.27	0.83909
11	12	11.03	0.52608
12	12	7.03	0.85553
13	12	7.14	0.84789
14	12	6.60	0.88266
15	12	17.45	0.13335

16	12	9.57	0.65383
17	12	12.35	0.41784
18	12	17.34	0.13711
19	12	15.09	0.23635
20	12	16.75	0.15922
21	12	15.94	0.19411
22	12	9.70	0.64185
23	12	21.96	0.03797
24	12	6.95	0.86114
25	12	28.09	0.00537
26	12	22.86	0.02893
27	12	7.96	0.78840
28	12	8.39	0.75430
29	12	13.12	0.36003
30	12	11.65	0.47399
31	12	17.50	0.13166
32	12	16.64	0.16357
33	12	16.70	0.16129
34	12	11.11	0.51962
35	12	9.36	0.67174
36	12	22.95	0.02817
37	12	13.43	0.33859
38	12	6.08	0.91181
39	12	14.58	0.26516
40	12	9.21	0.68504
41	12	9.73	0.63998
42	12	7.05	0.85427
43	12	6.32	0.89923
44	12	17.38	0.13595
45	12	8.40	0.75295
46	12	11.76	0.46486
47	12	8.85	0.71596
48	12	16.18	0.18308
49	12	25.46	0.01277
50	12	13.40	0.34055
51	12	9.56	0.65425
52	12	8.72	0.72685
53	12	9.45	0.66392
54	12	9.61	0.65031
55	12	10.02	0.61443
56	12	7.87	0.79501
57	12	11.68	0.47212
58	12	8.97	0.70541
59	12	21.59	0.04241
60	12	11.62	0.47695
61	12	12.47	0.40903
62	12	14.82	0.25125
63	12	14.59	0.26442
64	12	16.41	0.17302
65	12	19.85	0.06994
66	12	28.00	0.00553
67	12	8.57	0.73914
68	12	3.32	0.99285
69	12	6.93	0.86220
70	12	22.23	0.03503

71	12	9.16	0.68944
72	12	12.27	0.42418
73	12	6.85	0.86765
74	12	18.23	0.10891
75	12	5.29	0.94759
76	12	18.08	0.11329
77	12	9.02	0.70115
78	12	14.28	0.28349
79	12	11.92	0.45249
80	12	10.33	0.58708
81	12	11.21	0.51072
82	12	12.06	0.44082
83	12	18.90	0.09100
84	12	6.60	0.88271
85	12	6.45	0.89191
86	12	13.87	0.30882
87	12	13.10	0.36161
88	12	7.70	0.80818
89	12	9.46	0.66335
90	12	18.54	0.10028
91	12	10.01	0.61500
92	12	15.27	0.22714
93	12	7.33	0.83530
94	12	8.14	0.77400
95	12	19.10	0.08624
96	12	11.17	0.51421
97	12	7.26	0.83971
98	12	12.06	0.44082
99	12	13.57	0.32880
100	12	8.76	0.72332
Combined P-value for all tests (Using KS method)			0.74658

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)	0.97614	1.00000
Opening Score (Dealer)	0.72900	1.00000
Dealer's Final Score	0.33197	1.00000
Player Cards Rank	0.79691	1.00000
Dealer Cards Rank	0.74658	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.

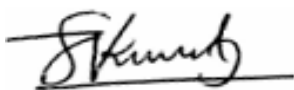
We conclude that the Random Number Generator (RNG) is working correctly.

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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iTech Labs Australia
Date: 03 June, 2021

Signed:



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Date: 03 June, 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.