



Blackjack Cards Analysis – November 2022

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **November 01, 2022 to November 30, 2022** 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	7.65	0.97346
2	17	16.61	0.48099
3	17	12.31	0.78129
4	17	21.81	0.19229
5	17	12.03	0.79823
6	17	13.63	0.69285
7	17	12.61	0.76179
8	17	8.19	0.96229
9	17	23.36	0.13780
10	17	16.84	0.46495
11	17	22.23	0.17606
12	17	26.99	0.05822
13	17	17.00	0.45436
14	17	19.25	0.31421
15	17	12.88	0.74414
16	17	9.03	0.93934
17	17	8.05	0.96547
18	17	11.12	0.85047
19	17	20.73	0.23858
20	17	16.91	0.46047
21	17	14.83	0.60773
22	17	22.35	0.17170
23	17	13.02	0.73466

24	17	18.06	0.38475
25	17	12.20	0.78757
26	17	17.72	0.40639
27	17	30.19	0.02502
28	17	15.58	0.55354
29	17	13.32	0.71460
30	17	14.54	0.62880
31	17	5.20	0.99714
32	17	13.74	0.68524
33	17	22.59	0.16308
34	17	7.45	0.97696
35	17	6.57	0.98848
36	17	18.29	0.37096
37	17	18.81	0.33957
38	17	15.22	0.57992
39	17	23.35	0.13805
40	17	14.78	0.61151
41	17	10.72	0.87089
42	17	12.72	0.75455
43	17	17.39	0.42796
44	17	7.81	0.97045
45	17	12.29	0.78229
46	17	15.29	0.57432
47	17	16.19	0.51069
48	17	8.25	0.96090
49	17	13.60	0.69543
50	17	19.80	0.28452
51	17	14.89	0.60314
52	17	9.20	0.93391
53	17	17.00	0.45425
54	17	17.14	0.44513
55	17	16.53	0.48671
56	17	11.43	0.83338
57	17	19.47	0.30217
58	17	12.12	0.79275
59	17	18.57	0.35357
60	17	11.60	0.82348
61	17	17.34	0.43146
62	17	6.45	0.98966
63	17	12.14	0.79159
64	17	12.87	0.74485
65	17	12.28	0.78260
66	17	17.04	0.45182
67	17	12.46	0.77154
68	17	9.09	0.93724
69	17	17.26	0.43674
70	17	18.48	0.35929
71	17	18.54	0.35542
72	17	20.11	0.26866
73	17	14.37	0.64051
74	17	28.38	0.04065
75	17	14.99	0.59623
76	17	16.01	0.52278
77	17	8.05	0.96550
78	17	23.21	0.14260

79	17	25.59	0.08235
80	17	12.06	0.79679
81	17	13.90	0.67386
82	17	7.16	0.98134
83	17	19.75	0.28720
84	17	8.92	0.94286
85	17	8.35	0.95848
86	17	18.28	0.37143
87	17	17.43	0.42550
88	17	11.49	0.82997
89	17	11.64	0.82144
90	17	28.47	0.03978
91	17	32.85	0.01177
92	17	15.32	0.57221
93	17	21.81	0.19207
94	17	36.25	0.00424
95	17	16.20	0.50990
96	17	12.67	0.75786
97	17	16.75	0.47136
98	17	16.61	0.48100
99	17	21.38	0.20968
100	17	7.42	0.97740
Combined P-value for all tests (Using KS method)			0.07885

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	30.31	0.02422
2	17	14.70	0.61681
3	17	13.77	0.68299
4	17	14.10	0.66010
5	17	24.71	0.10142
6	17	21.05	0.22405
7	17	11.53	0.82750
8	17	10.99	0.85698
9	17	18.57	0.35356
10	17	25.43	0.08552
11	17	20.24	0.26232
12	17	10.42	0.88520
13	17	25.60	0.08207
14	17	17.09	0.44812
15	17	15.59	0.55308
16	17	24.60	0.10398
17	17	14.65	0.62077
18	17	22.72	0.15855
19	17	14.99	0.59613
20	17	23.10	0.14613
21	17	17.60	0.41426
22	17	18.58	0.35328
23	17	15.45	0.56277

24	17	12.26	0.78401
25	17	8.03	0.96588
26	17	23.37	0.13753
27	17	25.98	0.07479
28	17	16.98	0.45558
29	17	14.42	0.63710
30	17	15.16	0.58369
31	17	11.52	0.82801
32	17	10.84	0.86454
33	17	14.37	0.64048
34	17	20.93	0.22955
35	17	9.65	0.91751
36	17	13.61	0.69429
37	17	9.48	0.92399
38	17	28.25	0.04215
39	17	8.15	0.96318
40	17	14.23	0.65080
41	17	19.57	0.29661
42	17	13.08	0.73074
43	17	15.92	0.52931
44	17	20.18	0.26506
45	17	6.94	0.98427
46	17	31.02	0.01987
47	17	6.83	0.98566
48	17	12.49	0.76953
49	17	13.31	0.71540
50	17	16.17	0.51215
51	17	14.06	0.66300
52	17	14.20	0.65321
53	17	15.19	0.58204
54	17	16.07	0.51890
55	17	19.18	0.31808
56	17	16.45	0.49223
57	17	20.89	0.23120
58	17	9.08	0.93777
59	17	8.56	0.95303
60	17	14.30	0.64584
61	17	14.94	0.60007
62	17	10.80	0.86690
63	17	30.54	0.02268
64	17	17.02	0.45279
65	17	18.01	0.38805
66	17	15.05	0.59184
67	17	15.30	0.57361
68	17	38.10	0.00238
69	17	24.59	0.10422
70	17	14.79	0.61095
71	17	13.57	0.69713
72	17	11.69	0.81847
73	17	18.63	0.35038
74	17	15.31	0.57285
75	17	21.70	0.19662
76	17	13.61	0.69469
77	17	11.15	0.84867
78	17	23.66	0.12905

79	17	14.26	0.64892
80	17	20.99	0.22680
81	17	11.75	0.81505
82	17	19.24	0.31484
83	17	18.86	0.33663
84	17	18.53	0.35596
85	17	24.92	0.09651
86	17	18.50	0.35800
87	17	25.99	0.07456
88	17	18.76	0.34275
89	17	13.54	0.69925
90	17	18.78	0.34148
91	17	16.44	0.49286
92	17	16.29	0.50324
93	17	14.53	0.62955
94	17	16.26	0.50583
95	17	25.14	0.09164
96	17	21.32	0.21242
97	17	13.47	0.70426
98	17	17.26	0.43718
99	17	19.79	0.28514
100	17	13.41	0.70800
Combined P-value for all tests (Using KS method)			0.61737

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	41.58	0.79595
2	50	40.11	0.84006
3	50	44.20	0.70419
4	50	43.81	0.71880
5	50	48.14	0.54841
6	50	41.67	0.79290
7	50	65.57	0.06881
8	50	46.75	0.60452
9	50	80.85	0.00373
10	50	49.06	0.51101
11	50	61.93	0.11998
12	50	66.49	0.05924
13	50	50.47	0.45499
14	50	57.10	0.22812
15	50	50.09	0.46985
16	50	59.18	0.17549
17	50	42.37	0.76979
18	50	65.67	0.06775
19	50	56.58	0.24286
20	50	58.63	0.18851
21	50	32.64	0.97269
22	50	37.23	0.90943
23	50	50.28	0.46225

24	50	50.45	0.45565
25	50	53.36	0.34636
26	50	54.55	0.30555
27	50	46.86	0.60006
28	50	41.81	0.78847
29	50	58.97	0.18030
30	50	64.82	0.07756
31	50	49.52	0.49242
32	50	53.42	0.34435
33	50	47.97	0.55517
34	50	58.70	0.18686
35	50	66.09	0.06323
36	50	46.97	0.59575
37	50	46.31	0.62240
38	50	42.66	0.75969
39	50	36.34	0.92604
40	50	47.60	0.57036
41	50	63.55	0.09443
42	50	40.00	0.84322
43	50	64.84	0.07727
44	50	36.06	0.93078
45	50	41.09	0.81114
46	50	48.48	0.53448
47	50	44.83	0.68015
48	50	40.10	0.84050
49	50	54.25	0.31553
50	50	41.41	0.80118
51	50	43.62	0.72558
52	50	36.03	0.93131
53	50	55.97	0.26084
54	50	69.12	0.03786
55	50	60.78	0.14124
56	50	43.10	0.74445
57	50	52.39	0.38147
58	50	39.84	0.84778
59	50	60.44	0.14801
60	50	48.84	0.52009
61	50	42.11	0.77850
62	50	43.73	0.72177
63	50	51.02	0.43326
64	50	36.76	0.91852
65	50	30.43	0.98693
66	50	32.94	0.97014
67	50	55.18	0.28535
68	50	54.74	0.29946
69	50	51.25	0.42430
70	50	45.76	0.64416
71	50	46.59	0.61097
72	50	46.92	0.59765
73	50	64.89	0.07666
74	50	61.29	0.13149
75	50	45.27	0.66345
76	50	32.99	0.96965
77	50	60.00	0.15714
78	50	39.83	0.84801

79	50	52.78	0.36701
80	50	38.80	0.87457
81	50	38.65	0.87837
82	50	50.60	0.44973
83	50	47.91	0.55750
84	50	46.83	0.60145
85	50	46.81	0.60211
86	50	42.09	0.77925
87	50	44.50	0.69287
88	50	60.82	0.14056
89	50	40.84	0.81888
90	50	46.98	0.59525
91	50	42.45	0.76704
92	50	36.98	0.91426
93	50	37.22	0.90962
94	50	48.73	0.52460
95	50	50.78	0.44266
96	50	37.48	0.90439
97	50	59.74	0.16289
98	50	53.12	0.35492
99	50	54.65	0.30239
100	50	48.93	0.51620
Combined P-value for all tests			0.45912

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	7.72	0.80630
2	12	8.51	0.74386
3	12	10.44	0.57704
4	12	11.12	0.51842
5	12	11.09	0.52120
6	12	13.97	0.30243
7	12	8.60	0.73632
8	12	10.92	0.53588
9	12	18.68	0.09668
10	12	8.12	0.77551
11	12	13.64	0.32396
12	12	7.32	0.83545
13	12	9.46	0.66304
14	12	11.64	0.47464
15	12	16.24	0.18067

16	12	3.21	0.99389
17	12	7.60	0.81569
18	12	6.17	0.90745
19	12	9.94	0.62088
20	12	21.52	0.04324
21	12	10.04	0.61283
22	12	6.11	0.91032
23	12	14.70	0.25805
24	12	10.01	0.61468
25	12	10.36	0.58456
26	12	8.55	0.74111
27	12	10.87	0.53973
28	12	9.78	0.63513
29	12	6.16	0.90793
30	12	15.52	0.21398
31	12	8.40	0.75333
32	12	6.41	0.89400
33	12	11.02	0.52731
34	12	7.27	0.83950
35	12	12.57	0.40119
36	12	17.92	0.11816
37	12	7.23	0.84204
38	12	12.34	0.41916
39	12	9.07	0.69697
40	12	8.29	0.76211
41	12	13.85	0.31031
42	12	6.63	0.88084
43	12	19.08	0.08666
44	12	9.69	0.64303
45	12	11.34	0.50032
46	12	13.32	0.34595
47	12	9.30	0.67708
48	12	18.48	0.10192
49	12	9.84	0.63029
50	12	9.65	0.64687
51	12	26.57	0.00892
52	12	9.11	0.69385
53	12	9.82	0.63190
54	12	10.80	0.54627
55	12	13.58	0.32830
56	12	11.70	0.46976
57	12	8.52	0.74356
58	12	18.23	0.10892
59	12	3.50	0.99087
60	12	29.02	0.00391
61	12	7.12	0.84933
62	12	5.55	0.93707
63	12	8.76	0.72340
64	12	7.15	0.84767
65	12	11.07	0.52264
66	12	13.36	0.34339
67	12	8.58	0.73802
68	12	17.63	0.12737
69	12	13.62	0.32575
70	12	8.22	0.76793

71	12	9.38	0.67043
72	12	5.27	0.94850
73	12	5.58	0.93561
74	12	9.08	0.69574
75	12	21.65	0.04163
76	12	9.94	0.62126
77	12	15.35	0.22277
78	12	13.61	0.32639
79	12	6.63	0.88132
80	12	15.34	0.22355
81	12	12.40	0.41416
82	12	11.15	0.51633
83	12	7.11	0.85019
84	12	8.78	0.72181
85	12	11.32	0.50152
86	12	9.33	0.67467
87	12	6.25	0.90275
88	12	9.93	0.62223
89	12	7.20	0.84422
90	12	9.17	0.68802
91	12	4.57	0.97090
92	12	9.32	0.67563
93	12	23.93	0.02081
94	12	15.20	0.23046
95	12	8.21	0.76869
96	12	12.88	0.37765
97	12	16.59	0.16574
98	12	7.54	0.82028
99	12	14.31	0.28136
100	12	6.27	0.90190
Combined P-value for all tests (Using KS method)			0.00519

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	27.68	0.00616
2	12	10.93	0.53521
3	12	9.74	0.63876
4	12	6.52	0.88788
5	12	7.43	0.82790
6	12	13.29	0.34853
7	12	8.59	0.73772
8	12	8.77	0.72269
9	12	17.05	0.14762
10	12	9.30	0.67679
11	12	10.64	0.56014
12	12	8.64	0.73344
13	12	13.05	0.36562
14	12	6.66	0.87950
15	12	11.90	0.45400

16	12	10.53	0.56944
17	12	10.80	0.54632
18	12	11.51	0.48562
19	12	29.79	0.00301
20	12	16.09	0.18695
21	12	12.75	0.38716
22	12	23.01	0.02763
23	12	11.74	0.46681
24	12	5.70	0.93031
25	12	10.72	0.55287
26	12	13.44	0.33792
27	12	9.49	0.66078
28	12	11.86	0.45728
29	12	6.61	0.88223
30	12	9.33	0.67449
31	12	8.73	0.72605
32	12	10.62	0.56164
33	12	16.60	0.16539
34	12	14.33	0.28039
35	12	5.47	0.94048
36	12	5.43	0.94207
37	12	12.72	0.38984
38	12	14.81	0.25206
39	12	8.90	0.71136
40	12	11.11	0.51968
41	12	12.99	0.36960
42	12	6.24	0.90370
43	12	8.35	0.75700
44	12	12.33	0.41927
45	12	4.24	0.97873
46	12	20.76	0.05404
47	12	9.25	0.68184
48	12	6.37	0.89657
49	12	14.04	0.29843
50	12	10.16	0.60188
51	12	11.31	0.50262
52	12	7.49	0.82348
53	12	5.84	0.92388
54	12	11.38	0.49664
55	12	7.43	0.82765
56	12	11.25	0.50741
57	12	12.01	0.44497
58	12	5.83	0.92443
59	12	12.61	0.39764
60	12	11.36	0.49829
61	12	19.04	0.08763
62	12	22.72	0.03015
63	12	19.27	0.08218
64	12	11.91	0.45316
65	12	14.88	0.24820
66	12	17.51	0.13136
67	12	9.05	0.69850
68	12	14.70	0.25826
69	12	8.77	0.72218
70	12	4.20	0.97962

71	12	7.91	0.79234
72	12	5.92	0.92004
73	12	12.89	0.37745
74	12	19.29	0.08175
75	12	4.42	0.97453
76	12	19.79	0.07124
77	12	14.51	0.26920
78	12	8.73	0.72555
79	12	10.62	0.56137
80	12	11.20	0.51161
81	12	6.91	0.86357
82	12	8.78	0.72199
83	12	14.01	0.30001
84	12	6.94	0.86140
85	12	15.40	0.22027
86	12	10.88	0.53892
87	12	23.91	0.02091
88	12	5.38	0.94413
89	12	16.12	0.18558
90	12	12.55	0.40263
91	12	13.58	0.32800
92	12	12.66	0.39392
93	12	7.51	0.82209
94	12	6.46	0.89126
95	12	6.60	0.88316
96	12	5.94	0.91895
97	12	25.31	0.01343
98	12	9.22	0.68373
99	12	6.31	0.89944
100	12	6.10	0.91113
Combined P-value for all tests (Using KS method)			0.30501

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)	0.07885	0.31540
Opening Score (Dealer)	0.61737	0.91824
Dealer's Final Score	0.45912	0.91824
Player Cards Rank	0.00519	0.02593
Dealer Cards Rank	0.30501	0.91503
Combined P-Value using Holm's Method		0.02593

Notes:

Truly random numbers are expected to produce patterns occasionally. '95% confidence tests' should report a failure 5% of the time if the input is truly random. We investigate each 'fail' to ensure they do not repeat more often than the expected 5% of the time.

Our overall result for this period was a 'fail', due to a failing Rank of Player cards test. 100 further chi-square tests were conducted, and only 5 of the 100 tests 'failed', which matched statistical expectation. Hence our conclusion is that the failure observed is a chance occurrence and does not indicate any systemic failure..

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.

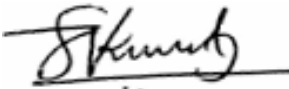
We conclude that the Random Number Generator (RNG) is working correctly.

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: 07 December, 2022

Signed:



Gyulserian Hyussein
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Date: 07 December, 2022

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.