



Blackjack Cards Analysis – June 2023

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **June 01, 2023 to June 30, 2023** 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	17.54	0.41855
2	17	18.89	0.33464
3	17	15.81	0.53733
4	17	20.97	0.22747
5	17	23.37	0.13756
6	17	11.24	0.84361
7	17	20.00	0.27408
8	17	23.37	0.13759
9	17	19.30	0.31139
10	17	17.22	0.43957
11	17	14.29	0.64680
12	17	15.95	0.52750
13	17	9.96	0.90511
14	17	11.43	0.83354
15	17	12.75	0.75258
16	17	24.01	0.11912
17	17	17.42	0.42596
18	17	15.32	0.57252
19	17	14.99	0.59589
20	17	13.14	0.72664
21	17	21.24	0.21575
22	17	19.58	0.29646
23	17	20.04	0.27198
24	17	24.24	0.11315

25	17	16.82	0.46640
26	17	10.01	0.90317
27	17	11.71	0.81708
28	17	14.36	0.64144
29	17	15.19	0.58189
30	17	14.05	0.66390
31	17	16.36	0.49870
32	17	12.93	0.74118
33	17	18.66	0.34839
34	17	16.84	0.46557
35	17	9.71	0.91540
36	17	14.93	0.60048
37	17	14.73	0.61527
38	17	18.05	0.38563
39	17	15.72	0.54354
40	17	14.12	0.65872
41	17	21.28	0.21407
42	17	13.27	0.71803
43	17	10.89	0.86237
44	17	19.46	0.30304
45	17	17.61	0.41401
46	17	17.84	0.39888
47	17	19.03	0.32681
48	17	12.26	0.78428
49	17	16.77	0.47006
50	17	15.16	0.58394
51	17	15.36	0.56941
52	17	11.15	0.84876
53	17	15.92	0.52981
54	17	20.92	0.22997
55	17	12.25	0.78467
56	17	4.80	0.99828
57	17	6.94	0.98425
58	17	17.56	0.41730
59	17	23.42	0.13612
60	17	12.03	0.79837
61	17	13.04	0.73322
62	17	21.60	0.20051
63	17	22.32	0.17256
64	17	13.78	0.68286
65	17	15.22	0.57952
66	17	15.90	0.53086
67	17	22.41	0.16935
68	17	16.56	0.48429
69	17	24.31	0.11128
70	17	17.00	0.45432
71	17	22.44	0.16851
72	17	14.33	0.64374
73	17	13.26	0.71870
74	17	14.17	0.65498
75	17	28.11	0.04365
76	17	9.42	0.92620
77	17	22.92	0.15201
78	17	8.78	0.94681
79	17	20.04	0.27219
80	17	13.81	0.68038

81	17	25.96	0.07513
82	17	15.13	0.58630
83	17	23.11	0.14556
84	17	19.49	0.30121
85	17	20.40	0.25448
86	17	13.60	0.69505
87	17	22.33	0.17243
88	17	18.39	0.36435
89	17	13.60	0.69549
90	17	16.45	0.49240
91	17	20.86	0.23278
92	17	23.89	0.12244
93	17	31.07	0.01957
94	17	10.13	0.89805
95	17	15.20	0.58107
96	17	21.03	0.22511
97	17	12.95	0.73975
98	17	23.60	0.13066
99	17	15.50	0.55940
100	17	14.00	0.66717
Combined P-value for all tests (Using KS method)			0.50654

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	16.92	0.45960
2	17	24.89	0.09716
3	17	16.65	0.47840
4	17	19.50	0.30053
5	17	20.79	0.23577
6	17	11.83	0.81047
7	17	9.21	0.93344
8	17	10.76	0.86892
9	17	25.50	0.08414
10	17	12.10	0.79420
11	17	13.95	0.67095
12	17	12.64	0.76010
13	17	18.73	0.34434
14	17	20.71	0.23946
15	17	29.51	0.03014
16	17	12.42	0.77409
17	17	22.79	0.15609
18	17	11.46	0.83179
19	17	23.58	0.13124
20	17	16.82	0.46693
21	17	30.12	0.02548
22	17	11.33	0.83885
23	17	6.29	0.99100
24	17	11.65	0.82075
25	17	11.73	0.81611
26	17	14.94	0.59956

27	17	21.95	0.18679
28	17	14.08	0.66114
29	17	23.15	0.14442
30	17	22.66	0.16078
31	17	14.71	0.61604
32	17	16.77	0.46983
33	17	16.84	0.46559
34	17	20.72	0.23921
35	17	19.53	0.29908
36	17	12.03	0.79854
37	17	12.96	0.73869
38	17	27.33	0.05345
39	17	11.30	0.84076
40	17	14.65	0.62075
41	17	11.21	0.84544
42	17	16.47	0.49081
43	17	12.66	0.75862
44	17	15.93	0.52906
45	17	16.07	0.51873
46	17	17.20	0.44095
47	17	22.88	0.15325
48	17	22.76	0.15737
49	17	15.33	0.57173
50	17	13.62	0.69361
51	17	10.41	0.88570
52	17	22.91	0.15227
53	17	11.07	0.85284
54	17	15.33	0.57163
55	17	26.20	0.07081
56	17	17.27	0.43601
57	17	17.70	0.40825
58	17	18.14	0.38011
59	17	10.10	0.89958
60	17	15.01	0.59449
61	17	10.40	0.88604
62	17	25.78	0.07849
63	17	16.24	0.50698
64	17	19.26	0.31394
65	17	17.16	0.44335
66	17	15.70	0.54541
67	17	16.32	0.50135
68	17	27.84	0.04689
69	17	17.29	0.43471
70	17	19.46	0.30288
71	17	17.35	0.43079
72	17	10.66	0.87392
73	17	18.75	0.34300
74	17	19.97	0.27583
75	17	9.33	0.92928
76	17	22.34	0.17196
77	17	21.82	0.19161
78	17	10.12	0.89872
79	17	18.10	0.38284
80	17	28.38	0.04071
81	17	18.67	0.34799
82	17	19.03	0.32709

83	17	12.76	0.75234
84	17	23.29	0.14018
85	17	18.11	0.38183
86	17	14.41	0.63802
87	17	11.44	0.83301
88	17	13.35	0.71234
89	17	23.64	0.12947
90	17	18.73	0.34412
91	17	24.98	0.09512
92	17	17.82	0.39999
93	17	11.96	0.80227
94	17	24.82	0.09892
95	17	21.72	0.19590
96	17	12.85	0.74640
97	17	9.91	0.90740
98	17	13.11	0.72880
99	17	13.50	0.70224
100	17	24.01	0.11908
Combined P-value for all tests (Using KS method)			0.93893

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	64.37	0.08320
2	50	42.48	0.76605
3	50	45.59	0.65096
4	50	30.83	0.98495
5	50	22.93	0.99964
6	50	52.52	0.37672
7	50	46.30	0.62269
8	50	51.28	0.42339
9	50	61.86	0.12120
10	50	68.68	0.04085
11	50	48.77	0.52283
12	50	62.62	0.10849
13	50	66.36	0.06048
14	50	50.73	0.44479
15	50	59.56	0.16687
16	50	33.93	0.96017
17	50	53.06	0.35714
18	50	38.69	0.87736
19	50	45.80	0.64253
20	50	44.33	0.69925
21	50	60.05	0.15610
22	50	45.87	0.63967
23	50	39.88	0.84654
24	50	55.76	0.26728
25	50	39.95	0.84455
26	50	62.65	0.10803
27	50	53.41	0.34476
28	50	34.44	0.95418

29	50	49.37	0.49879
30	50	32.90	0.97041
31	50	37.95	0.89442
32	50	58.05	0.20295
33	50	21.77	0.99983
34	50	58.17	0.19985
35	50	52.99	0.35969
36	50	50.65	0.44775
37	50	49.04	0.51181
38	50	50.13	0.46843
39	50	31.86	0.97866
40	50	65.76	0.06668
41	50	89.06	0.00056
42	50	60.35	0.14995
43	50	41.91	0.78524
44	50	70.22	0.03112
45	50	66.31	0.06103
46	50	65.46	0.07007
47	50	46.78	0.60355
48	50	60.84	0.14016
49	50	38.28	0.88702
50	50	54.11	0.32029
51	50	47.50	0.57415
52	50	64.15	0.08610
53	50	55.59	0.27245
54	50	47.09	0.59081
55	50	58.03	0.20343
56	50	76.66	0.00903
57	50	64.07	0.08713
58	50	40.52	0.82840
59	50	31.08	0.98356
60	50	50.96	0.43549
61	50	54.59	0.30420
62	50	49.23	0.50415
63	50	46.52	0.61402
64	50	49.43	0.49612
65	50	65.28	0.07210
66	50	67.33	0.05148
67	50	67.77	0.04782
68	50	47.62	0.56935
69	50	66.94	0.05499
70	50	54.67	0.30171
71	50	54.69	0.30107
72	50	54.82	0.29691
73	50	47.54	0.57265
74	50	58.47	0.19238
75	50	29.56	0.99053
76	50	43.35	0.73532
77	50	60.25	0.15195
78	50	44.86	0.67916
79	50	43.64	0.72516
80	50	40.43	0.83086
81	50	40.09	0.84064
82	50	42.59	0.76222
83	50	55.87	0.26369
84	50	59.03	0.17883

85	50	45.01	0.67352
86	50	54.92	0.29371
87	50	43.55	0.72817
88	50	50.25	0.46338
89	50	62.32	0.11339
90	50	39.19	0.86492
91	50	72.73	0.01956
92	50	48.91	0.51705
93	50	64.75	0.07840
94	50	50.73	0.44443
95	50	54.44	0.30934
96	50	62.28	0.11403
97	50	54.65	0.30227
98	50	61.17	0.13374
99	50	60.59	0.14506
100	50	65.45	0.07018
Combined P-value for all tests			0.04348

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	18.45	0.10266
2	12	12.60	0.39864
3	12	7.04	0.85523
4	12	8.86	0.71462
5	12	7.63	0.81327
6	12	10.87	0.54009
7	12	16.30	0.17804
8	12	13.10	0.36199
9	12	9.14	0.69055
10	12	7.16	0.84691
11	12	12.37	0.41661
12	12	7.50	0.82317
13	12	11.88	0.45499
14	12	3.95	0.98435
15	12	17.80	0.12205
16	12	7.06	0.85345
17	12	10.97	0.53109
18	12	8.89	0.71226
19	12	5.32	0.94657
20	12	12.80	0.38378
21	12	20.17	0.06388
22	12	19.46	0.07805

23	12	6.51	0.88823
24	12	14.41	0.27521
25	12	21.11	0.04880
26	12	10.94	0.53410
27	12	4.63	0.96918
28	12	15.66	0.20736
29	12	17.68	0.12561
30	12	9.20	0.68571
31	12	11.31	0.50279
32	12	8.62	0.73463
33	12	10.69	0.55551
34	12	7.59	0.81631
35	12	9.29	0.67839
36	12	25.78	0.01153
37	12	2.76	0.99700
38	12	5.22	0.95041
39	12	10.73	0.55224
40	12	14.43	0.27429
41	12	14.19	0.28894
42	12	10.75	0.55085
43	12	17.25	0.14039
44	12	9.72	0.64024
45	12	14.53	0.26807
46	12	12.04	0.44209
47	12	19.83	0.07044
48	12	10.78	0.54809
49	12	13.48	0.33493
50	12	12.94	0.37350
51	12	5.66	0.93245
52	12	9.91	0.62423
53	12	7.62	0.81376
54	12	3.70	0.98832
55	12	9.55	0.65496
56	12	12.73	0.38877
57	12	4.55	0.97126
58	12	13.10	0.36193
59	12	11.59	0.47945
60	12	23.56	0.02330
61	12	6.10	0.91091
62	12	4.87	0.96227
63	12	12.23	0.42741
64	12	6.36	0.89688
65	12	8.76	0.72304
66	12	6.29	0.90057
67	12	13.22	0.35312
68	12	7.99	0.78554
69	12	13.46	0.33639
70	12	13.55	0.33013
71	12	16.38	0.17431
72	12	9.75	0.63796
73	12	12.44	0.41124
74	12	13.50	0.33383
75	12	15.66	0.20728
76	12	8.08	0.77877
77	12	11.92	0.45192
78	12	11.53	0.48411

79	12	18.61	0.09833
80	12	4.91	0.96106
81	12	12.50	0.40651
82	12	13.85	0.31043
83	12	12.10	0.43742
84	12	14.54	0.26765
85	12	5.67	0.93200
86	12	8.58	0.73795
87	12	11.89	0.45427
88	12	9.53	0.65713
89	12	20.33	0.06113
90	12	13.25	0.35128
91	12	17.41	0.13478
92	12	13.97	0.30270
93	12	16.17	0.18337
94	12	24.59	0.01690
95	12	13.55	0.33005
96	12	14.09	0.29511
97	12	10.47	0.57459
98	12	13.72	0.31882
99	12	9.43	0.66557
100	12	7.27	0.83934
Combined P-value for all tests (Using KS method)			0.56594

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	11.62	0.47628
2	12	11.76	0.46488
3	12	6.23	0.90430
4	12	16.12	0.18588
5	12	15.30	0.22561
6	12	13.56	0.33000
7	12	16.09	0.18710
8	12	13.07	0.36379
9	12	17.95	0.11708
10	12	16.70	0.16138
11	12	10.92	0.53567
12	12	11.84	0.45892
13	12	14.89	0.24778
14	12	9.95	0.62007
15	12	7.86	0.79596
16	12	12.62	0.39716
17	12	7.73	0.80617
18	12	17.67	0.12606
19	12	10.27	0.59260
20	12	16.63	0.16412
21	12	6.80	0.87060
22	12	7.57	0.81751
23	12	17.48	0.13254
24	12	12.41	0.41352

25	12	9.81	0.63250
26	12	16.58	0.16594
27	12	12.00	0.44565
28	12	3.93	0.98471
29	12	22.37	0.03361
30	12	15.55	0.21298
31	12	8.07	0.77964
32	12	3.90	0.98515
33	12	14.90	0.24723
34	12	7.52	0.82109
35	12	10.27	0.59271
36	12	9.75	0.63815
37	12	4.22	0.97908
38	12	7.75	0.80473
39	12	12.69	0.39221
40	12	5.33	0.94618
41	12	12.54	0.40352
42	12	6.83	0.86856
43	12	10.27	0.59255
44	12	5.76	0.92759
45	12	16.47	0.17062
46	12	20.44	0.05921
47	12	8.18	0.77065
48	12	6.67	0.87846
49	12	10.19	0.59933
50	12	14.88	0.24830
51	12	15.48	0.21648
52	12	13.86	0.30978
53	12	15.60	0.21025
54	12	7.28	0.83848
55	12	15.25	0.22816
56	12	11.57	0.48079
57	12	6.25	0.90313
58	12	17.17	0.14347
59	12	12.38	0.41592
60	12	17.47	0.13268
61	12	8.41	0.75239
62	12	10.19	0.59917
63	12	15.62	0.20915
64	12	11.78	0.46381
65	12	16.21	0.18200
66	12	9.44	0.66523
67	12	18.64	0.09756
68	12	8.02	0.78353
69	12	16.03	0.18996
70	12	14.20	0.28821
71	12	3.96	0.98411
72	12	7.15	0.84771
73	12	12.58	0.40022
74	12	5.64	0.93320
75	12	6.14	0.90903
76	12	7.14	0.84809
77	12	10.81	0.54528
78	12	16.26	0.17972
79	12	14.35	0.27913
80	12	19.65	0.07408

81	12	6.52	0.88757
82	12	27.19	0.00725
83	12	9.45	0.66399
84	12	10.23	0.59542
85	12	17.03	0.14840
86	12	21.65	0.04160
87	12	13.01	0.36858
88	12	27.31	0.00697
89	12	22.06	0.03680
90	12	12.89	0.37681
91	12	14.96	0.24377
92	12	10.61	0.56276
93	12	11.09	0.52147
94	12	8.94	0.70830
95	12	20.29	0.06178
96	12	8.85	0.71559
97	12	10.66	0.55792
98	12	9.34	0.67331
99	12	11.72	0.46880
100	12	21.21	0.04744
Combined P-value for all tests (Using KS method)			0.35392

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)	0.50654	1.00000
Opening Score (Dealer)	0.93893	1.00000
Dealer's Final Score	0.04348	0.21740
Player Cards Rank	0.56594	1.00000
Dealer Cards Rank	0.35392	1.00000
Combined P-Value using Holm's Method		0.21740

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.

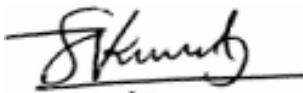
We conclude that the Random Number Generator (RNG) is working correctly.

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: 31 July 2023

Signed:



Gyulserian Hyussein
Senior Consultant
iTech Labs Australia
Date: 31 July 2023

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.

