



## Blackjack Cards Analysis – August 2023

### The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **August 01, 2023 to August 31, 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	16.45	0.49195
2	17	8.38	0.95781
3	17	18.66	0.34858
4	17	12.32	0.78012
5	17	16.37	0.49749
6	17	16.79	0.46861
7	17	10.51	0.88099
8	17	5.20	0.99715
9	17	15.71	0.54457
10	17	19.73	0.28802
11	17	19.49	0.30140
12	17	8.95	0.94188
13	17	15.26	0.57698
14	17	14.04	0.66419
15	17	19.61	0.29470
16	17	9.02	0.93976
17	17	13.27	0.71760
18	17	9.07	0.93798
19	17	23.90	0.12217
20	17	35.74	0.00497
21	17	17.69	0.40866

22	17	10.86	0.86389
23	17	23.10	0.14591
24	17	14.75	0.61370
25	17	15.17	0.58307
26	17	11.97	0.80204
27	17	18.94	0.33188
28	17	25.21	0.09011
29	17	21.94	0.18699
30	17	22.85	0.15414
31	17	15.20	0.58095
32	17	13.11	0.72905
33	17	16.43	0.49371
34	17	15.94	0.52831
35	17	15.44	0.56415
36	17	32.47	0.01317
37	17	24.30	0.11145
38	17	7.03	0.98313
39	17	20.27	0.26078
40	17	14.02	0.66567
41	17	15.53	0.55752
42	17	19.60	0.29512
43	17	22.68	0.15993
44	17	12.98	0.73733
45	17	16.30	0.50256
46	17	16.02	0.52207
47	17	8.49	0.95485
48	17	11.54	0.82704
49	17	14.39	0.63918
50	17	16.54	0.48618
51	17	11.16	0.84828
52	17	16.61	0.48076
53	17	11.07	0.85316
54	17	21.60	0.20074
55	17	13.06	0.73185
56	17	13.71	0.68780
57	17	16.68	0.47656
58	17	20.44	0.25227
59	17	26.93	0.05916
60	17	17.48	0.42216
61	17	11.09	0.85200
62	17	11.24	0.84408
63	17	18.94	0.33187
64	17	18.69	0.34681
65	17	16.62	0.48056
66	17	18.18	0.37781
67	17	10.41	0.88573
68	17	17.88	0.39616
69	17	13.76	0.68404
70	17	13.39	0.70991

71	17	19.70	0.28960
72	17	22.44	0.16855
73	17	12.56	0.76534
74	17	11.09	0.85198
75	17	24.46	0.10739
76	17	12.08	0.79552
77	17	16.64	0.47916
78	17	14.58	0.62553
79	17	23.52	0.13317
80	17	30.46	0.02319
81	17	17.30	0.43411
82	17	8.74	0.94803
83	17	17.17	0.44278
84	17	19.50	0.30043
85	17	14.22	0.65170
86	17	22.22	0.17644
87	17	9.46	0.92484
88	17	9.63	0.91839
89	17	23.45	0.13502
90	17	12.27	0.78355
91	17	18.39	0.36480
92	17	10.81	0.86617
93	17	17.51	0.42026
94	17	17.02	0.45332
95	17	22.32	0.17286
96	17	16.71	0.47387
97	17	26.41	0.06734
98	17	19.10	0.32283
99	17	15.31	0.57310
100	17	15.91	0.53012
Combined P-value for all tests (Using KS method)			0.55976

*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	8.13	0.96361
2	17	19.63	0.29359
3	17	12.58	0.76387
4	17	10.23	0.89381
5	17	25.66	0.08089
6	17	16.63	0.47997
7	17	18.40	0.36421
8	17	13.30	0.71610
9	17	7.80	0.97063
10	17	10.46	0.88307
11	17	19.06	0.32496
12	17	18.43	0.36199

13	17	18.94	0.33215
14	17	10.83	0.86526
15	17	26.75	0.06181
16	17	11.94	0.80357
17	17	8.43	0.95657
18	17	15.50	0.55952
19	17	20.21	0.26341
20	17	12.33	0.77957
21	17	6.85	0.98542
22	17	19.40	0.30597
23	17	26.74	0.06206
24	17	21.51	0.20425
25	17	16.47	0.49079
26	17	14.39	0.63910
27	17	20.35	0.25689
28	17	18.42	0.36253
29	17	11.11	0.85096
30	17	14.81	0.60933
31	17	11.61	0.82328
32	17	26.72	0.06234
33	17	10.51	0.88085
34	17	10.03	0.90230
35	17	16.96	0.45727
36	17	22.55	0.16437
37	17	16.81	0.46714
38	17	34.17	0.00799
39	17	25.64	0.08134
40	17	34.63	0.00695
41	17	19.69	0.29048
42	17	20.64	0.24292
43	17	15.12	0.58666
44	17	17.95	0.39231
45	17	14.27	0.64759
46	17	10.12	0.89859
47	17	24.30	0.11159
48	17	24.10	0.11671
49	17	20.21	0.26378
50	17	17.78	0.40256
51	17	10.20	0.89505
52	17	20.46	0.25130
53	17	14.58	0.62550
54	17	21.21	0.21712
55	17	12.35	0.77852
56	17	16.09	0.51765
57	17	19.62	0.29425
58	17	15.17	0.58357
59	17	15.81	0.53730
60	17	24.23	0.11334
61	17	13.33	0.71355

62	17	19.90	0.27941
63	17	9.18	0.93445
64	17	15.07	0.59077
65	17	12.64	0.75965
66	17	9.55	0.92124
67	17	16.49	0.48959
68	17	29.49	0.03027
69	17	10.06	0.90096
70	17	12.08	0.79545
71	17	23.49	0.13402
72	17	7.45	0.97690
73	17	13.87	0.67610
74	17	15.74	0.54224
75	17	19.36	0.30833
76	17	21.60	0.20077
77	17	17.12	0.44654
78	17	13.47	0.70397
79	17	19.82	0.28339
80	17	15.59	0.55317
81	17	18.22	0.37535
82	17	20.44	0.25255
83	17	15.81	0.53762
84	17	14.61	0.62369
85	17	20.60	0.24456
86	17	8.52	0.95417
87	17	21.37	0.21026
88	17	12.76	0.75221
89	17	19.43	0.30434
90	17	11.56	0.82613
91	17	25.55	0.08303
92	17	16.70	0.47485
93	17	11.73	0.81628
94	17	12.94	0.74028
95	17	12.29	0.78204
96	17	13.08	0.73059
97	17	17.89	0.39567
98	17	14.82	0.60846
99	17	15.86	0.53374
100	17	23.35	0.13805
Combined P-value for all tests (Using KS method)			0.93602

*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	45.02	0.67291
2	50	64.28	0.08441
3	50	61.74	0.12339

4	50	47.62	0.56923
5	50	49.04	0.51186
6	50	55.63	0.27104
7	50	53.33	0.34736
8	50	52.44	0.37956
9	50	44.33	0.69950
10	50	55.57	0.27315
11	50	57.36	0.22103
12	50	72.42	0.02073
13	50	84.38	0.00170
14	50	66.81	0.05620
15	50	53.59	0.33831
16	50	57.81	0.20905
17	50	50.99	0.43448
18	50	38.24	0.88795
19	50	50.73	0.44466
20	50	35.01	0.94664
21	50	33.48	0.96490
22	50	31.89	0.97847
23	50	49.32	0.50068
24	50	34.01	0.95929
25	50	58.46	0.19265
26	50	49.20	0.50549
27	50	43.40	0.73362
28	50	42.61	0.76157
29	50	45.44	0.65652
30	50	36.34	0.92595
31	50	38.94	0.87117
32	50	45.01	0.67344
33	50	62.57	0.10923
34	50	51.37	0.41982
35	50	53.49	0.34178
36	50	50.12	0.46855
37	50	45.59	0.65071
38	50	32.26	0.97577
39	50	53.31	0.34822
40	50	55.20	0.28471
41	50	46.88	0.59952
42	50	55.19	0.28484
43	50	30.80	0.98509
44	50	43.80	0.71909
45	50	36.96	0.91466
46	50	51.84	0.40202
47	50	39.04	0.86867
48	50	55.06	0.28901
49	50	53.87	0.32869
50	50	46.01	0.63434
51	50	36.90	0.91586
52	50	58.32	0.19616

53	50	45.00	0.67365
54	50	47.54	0.57269
55	50	66.37	0.06037
56	50	45.70	0.64637
57	50	58.72	0.18625
58	50	48.70	0.52568
59	50	74.71	0.01335
60	50	75.14	0.01225
61	50	51.89	0.40011
62	50	47.01	0.59401
63	50	48.02	0.55301
64	50	44.87	0.67880
65	50	39.45	0.85825
66	50	53.05	0.35751
67	50	59.45	0.16934
68	50	47.95	0.55617
69	50	59.51	0.16796
70	50	53.49	0.34195
71	50	59.25	0.17378
72	50	40.23	0.83666
73	50	44.52	0.69220
74	50	60.94	0.13822
75	50	52.28	0.38533
76	50	56.70	0.23942
77	50	57.50	0.21725
78	50	60.40	0.14888
79	50	60.60	0.14490
80	50	53.78	0.33180
81	50	30.72	0.98552
82	50	57.25	0.22392
83	50	36.67	0.92006
84	50	43.65	0.72446
85	50	82.61	0.00253
86	50	67.61	0.04915
87	50	47.16	0.58816
88	50	44.69	0.68559
89	50	65.59	0.06856
90	50	40.69	0.82340
91	50	53.89	0.32776
92	50	57.44	0.21888
93	50	76.42	0.00948
94	50	61.89	0.12063
95	50	55.30	0.28131
96	50	59.69	0.16384
97	50	46.08	0.63158
98	50	53.43	0.34386
99	50	54.13	0.31985
100	50	38.27	0.88723
Combined P-value for all tests			0.23116

*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	9.99	0.61710
2	12	9.70	0.64265
3	12	11.86	0.45729
4	12	9.89	0.62604
5	12	17.90	0.11887
6	12	14.40	0.27574
7	12	11.25	0.50779
8	12	8.08	0.77874
9	12	11.67	0.47220
10	12	6.62	0.88175
11	12	10.16	0.60181
12	12	8.72	0.72681
13	12	14.55	0.26670
14	12	8.01	0.78461
15	12	8.96	0.70629
16	12	10.16	0.60204
17	12	11.23	0.50903
18	12	16.17	0.18366
19	12	14.92	0.24580
20	12	8.43	0.75085
21	12	11.10	0.52025
22	12	24.48	0.01747
23	12	23.23	0.02583
24	12	17.76	0.12303
25	12	25.11	0.01432
26	12	7.04	0.85483
27	12	12.15	0.43366
28	12	10.51	0.57119
29	12	10.24	0.59468
30	12	8.76	0.72311
31	12	14.69	0.25883
32	12	9.83	0.63099
33	12	15.84	0.19849
34	12	6.68	0.87806
35	12	15.00	0.24151
36	12	13.40	0.34074
37	12	7.43	0.82818



38	12	6.59	0.88348
39	12	8.33	0.75873
40	12	9.22	0.68415
41	12	11.29	0.50402
42	12	13.01	0.36856
43	12	20.30	0.06155
44	12	11.78	0.46318
45	12	26.66	0.00865
46	12	6.96	0.86033
47	12	4.81	0.96401
48	12	11.23	0.50954
49	12	16.00	0.19133
50	12	6.10	0.91089
51	12	3.94	0.98448
52	12	9.81	0.63292
53	12	14.91	0.24628
54	12	11.76	0.46476
55	12	10.58	0.56498
56	12	9.81	0.63222
57	12	11.93	0.45121
58	12	7.08	0.85246
59	12	10.49	0.57323
60	12	9.25	0.68156
61	12	12.30	0.42195
62	12	8.05	0.78153
63	12	4.96	0.95930
64	12	9.18	0.68720
65	12	9.66	0.64547
66	12	5.46	0.94080
67	12	6.13	0.90918
68	12	12.93	0.37410
69	12	6.63	0.88103
70	12	14.27	0.28351
71	12	21.09	0.04913
72	12	10.37	0.58313
73	12	8.51	0.74406
74	12	24.52	0.01725
75	12	13.05	0.36547
76	12	22.01	0.03745
77	12	8.28	0.76256
78	12	20.75	0.05413
79	12	5.44	0.94170
80	12	9.76	0.63660
81	12	9.00	0.70299
82	12	14.99	0.24176
83	12	10.42	0.57917
84	12	5.94	0.91888
85	12	12.87	0.37836
86	12	15.80	0.20076

87	12	9.96	0.61929
88	12	14.76	0.25490
89	12	5.20	0.95106
90	12	13.19	0.35562
91	12	5.74	0.92856
92	12	15.35	0.22309
93	12	12.01	0.44456
94	12	11.06	0.52356
95	12	11.12	0.51872
96	12	15.75	0.20280
97	12	13.32	0.34640
98	12	8.71	0.72754
99	12	4.71	0.96688
100	12	12.23	0.42729
Combined P-value for all tests (Using KS method)			0.35068

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	12.13	0.43554
2	12	7.25	0.84073
3	12	9.56	0.65449
4	12	7.10	0.85092
5	12	10.57	0.56622
6	12	11.91	0.45326
7	12	9.94	0.62122
8	12	13.42	0.33934
9	12	12.91	0.37531
10	12	14.87	0.24879
11	12	7.18	0.84582
12	12	12.97	0.37099
13	12	14.77	0.25426
14	12	10.68	0.55668
15	12	9.09	0.69504
16	12	5.26	0.94871
17	12	16.65	0.16334
18	12	8.56	0.74025
19	12	28.00	0.00553
20	12	12.50	0.40622
21	12	7.00	0.85778
22	12	14.10	0.29413
23	12	4.88	0.96184
24	12	17.77	0.12277
25	12	3.88	0.98558
26	12	14.86	0.24930
27	12	8.52	0.74299
28	12	4.75	0.96595
29	12	12.13	0.43552
30	12	19.12	0.08573
31	12	12.09	0.43843
32	12	22.21	0.03521

33	12	6.30	0.90027
34	12	13.50	0.33385
35	12	8.06	0.78010
36	12	11.99	0.44670
37	12	9.57	0.65326
38	12	20.19	0.06353
39	12	7.30	0.83720
40	12	8.38	0.75486
41	12	19.10	0.08603
42	12	7.90	0.79292
43	12	16.13	0.18543
44	12	13.89	0.30773
45	12	14.69	0.25867
46	12	12.72	0.38938
47	12	16.24	0.18067
48	12	13.95	0.30387
49	12	12.10	0.43798
50	12	12.64	0.39610
51	12	5.84	0.92400
52	12	9.56	0.65467
53	12	17.17	0.14345
54	12	9.63	0.64865
55	12	14.33	0.28000
56	12	7.89	0.79379
57	12	11.33	0.50085
58	12	10.82	0.54409
59	12	10.53	0.56970
60	12	11.68	0.47181
61	12	18.21	0.10955
62	12	18.06	0.11384
63	12	7.62	0.81392
64	12	10.81	0.54500
65	12	16.78	0.15813
66	12	7.23	0.84195
67	12	21.78	0.04012
68	12	17.08	0.14659
69	12	3.62	0.98937
70	12	7.83	0.79842
71	12	8.25	0.76539
72	12	9.07	0.69697
73	12	13.37	0.34247
74	12	13.52	0.33227
75	12	13.40	0.34038
76	12	8.86	0.71523
77	12	9.17	0.68821
78	12	6.78	0.87174
79	12	20.77	0.05388
80	12	14.73	0.25626
81	12	17.53	0.13088
82	12	4.75	0.96579
83	12	8.26	0.76420
84	12	6.85	0.86724
85	12	11.07	0.52333
86	12	16.87	0.15448
87	12	9.09	0.69492
88	12	10.94	0.53417

89	12	10.09	0.60782
90	12	17.28	0.13949
91	12	11.04	0.52507
92	12	4.41	0.97493
93	12	14.20	0.28803
94	12	7.02	0.85597
95	12	13.78	0.31485
96	12	8.30	0.76165
97	12	4.18	0.98003
98	12	16.46	0.17106
99	12	17.45	0.13346
100	12	12.53	0.40378
Combined P-value for all tests (Using KS method)			0.99631

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)	0.55976	1.00000
Opening Score (Dealer)	0.93602	1.00000
Dealer's Final Score	0.23116	1.00000
Player Cards Rank	0.35068	1.00000
Dealer Cards Rank	0.99631	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.

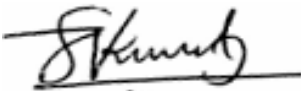
iTech Labs has done limited sanity checks to verify the integrity of the game logs. iTech Labs also maintains a copy of the game logs for verification purposes. There were a large enough number of game records to give the calculations sufficient statistical power.

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.

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**Signed:**



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**Kiren Sreekumar**  
**Principal Consultant**  
**iTech Labs Australia**

Date: 20 September 2023

**Signed:**



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**Alvin Rizaldi**  
**Senior Consultant**  
**iTech Labs Australia**

Date: 20 September 2023

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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.