



## Blackjack Cards Analysis – April 2023

### The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **April 01, 2023 to April 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	22.86	0.15376
2	17	15.12	0.58710
3	17	28.64	0.03798
4	17	12.63	0.76091
5	17	21.22	0.21660
6	17	16.93	0.45913
7	17	15.12	0.58658
8	17	11.91	0.80576
9	17	18.94	0.33199
10	17	17.37	0.42983
11	17	8.83	0.94544
12	17	18.46	0.36020
13	17	36.89	0.00349
14	17	13.59	0.69602
15	17	16.99	0.45536
16	17	19.74	0.28757
17	17	20.01	0.27358
18	17	14.90	0.60301
19	17	18.11	0.38223
20	17	33.47	0.00982
21	17	16.49	0.48973
22	17	17.16	0.44384
23	17	10.74	0.86986
24	17	17.48	0.42234

25	17	8.80	0.94645
26	17	22.31	0.17303
27	17	10.61	0.87597
28	17	18.17	0.37795
29	17	28.40	0.04044
30	17	25.36	0.08688
31	17	16.79	0.46834
32	17	20.29	0.25977
33	17	32.88	0.01166
34	17	14.12	0.65845
35	17	24.81	0.09895
36	17	12.02	0.79887
37	17	9.09	0.93755
38	17	15.14	0.58535
39	17	23.40	0.13665
40	17	11.50	0.82944
41	17	9.32	0.92966
42	17	18.30	0.37008
43	17	13.31	0.71499
44	17	22.14	0.17932
45	17	11.98	0.80143
46	17	17.87	0.39705
47	17	14.92	0.60160
48	17	12.17	0.78998
49	17	19.66	0.29214
50	17	20.87	0.23222
51	17	17.07	0.44945
52	17	22.22	0.17642
53	17	13.86	0.67724
54	17	18.93	0.33269
55	17	15.38	0.56834
56	17	27.30	0.05382
57	17	11.56	0.82583
58	17	19.88	0.28050
59	17	16.15	0.51300
60	17	14.24	0.65028
61	17	20.05	0.27149
62	17	17.14	0.44520
63	17	20.00	0.27435
64	17	13.91	0.67366
65	17	16.75	0.47158
66	17	17.69	0.40834
67	17	11.04	0.85441
68	17	13.68	0.68976
69	17	12.31	0.78118
70	17	23.53	0.13277
71	17	18.95	0.33131
72	17	24.24	0.11307
73	17	24.85	0.09822
74	17	20.05	0.27161
75	17	21.78	0.19328
76	17	27.48	0.05136
77	17	11.79	0.81280
78	17	15.13	0.58629
79	17	12.61	0.76163
80	17	20.64	0.24301

81	17	9.22	0.93326
82	17	24.02	0.11889
83	17	16.17	0.51172
84	17	11.49	0.82995
85	17	8.31	0.95941
86	17	15.21	0.58056
87	17	27.69	0.04868
88	17	21.50	0.20480
89	17	11.67	0.81956
90	17	10.33	0.88907
91	17	12.02	0.79897
92	17	16.78	0.46948
93	17	14.64	0.62171
94	17	16.25	0.50623
95	17	12.86	0.74548
96	17	13.53	0.70021
97	17	20.61	0.24421
98	17	12.67	0.75793
99	17	17.05	0.45125
100	17	14.56	0.62724
Combined P-value for all tests (Using KS method)			0.85303

*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	11.99	0.80072
2	17	9.91	0.90725
3	17	12.30	0.78163
4	17	26.30	0.06914
5	17	11.12	0.85042
6	17	9.20	0.93391
7	17	29.88	0.02725
8	17	13.60	0.69536
9	17	25.48	0.08443
10	17	15.99	0.52488
11	17	16.70	0.47503
12	17	15.92	0.52941
13	17	16.03	0.52136
14	17	13.46	0.70485
15	17	26.58	0.06445
16	17	23.26	0.14107
17	17	16.70	0.47469
18	17	28.18	0.04291
19	17	13.87	0.67596
20	17	22.98	0.14995
21	17	16.57	0.48414
22	17	22.52	0.16539
23	17	14.88	0.60442
24	17	10.40	0.88599
25	17	16.77	0.46977
26	17	12.32	0.78037

27	17	8.81	0.94615
28	17	28.40	0.04042
29	17	16.85	0.46439
30	17	22.01	0.18439
31	17	14.51	0.63044
32	17	15.34	0.57110
33	17	13.95	0.67069
34	17	10.24	0.89307
35	17	10.89	0.86241
36	17	11.06	0.85333
37	17	8.62	0.95147
38	17	20.65	0.24248
39	17	21.83	0.19129
40	17	17.33	0.43223
41	17	14.69	0.61760
42	17	15.81	0.53724
43	17	14.08	0.66109
44	17	13.65	0.69178
45	17	7.90	0.96870
46	17	14.26	0.64876
47	17	11.94	0.80361
48	17	16.02	0.52244
49	17	16.06	0.51935
50	17	20.33	0.25786
51	17	12.53	0.76717
52	17	12.99	0.73674
53	17	17.05	0.45065
54	17	16.83	0.46627
55	17	16.86	0.46363
56	17	18.26	0.37278
57	17	14.61	0.62369
58	17	22.04	0.18314
59	17	10.64	0.87453
60	17	21.69	0.19687
61	17	21.53	0.20350
62	17	18.09	0.38320
63	17	20.66	0.24197
64	17	21.54	0.20323
65	17	24.09	0.11698
66	17	10.91	0.86107
67	17	17.62	0.41329
68	17	18.87	0.33586
69	17	23.74	0.12680
70	17	39.41	0.00156
71	17	24.02	0.11890
72	17	15.61	0.55164
73	17	17.90	0.39520
74	17	15.12	0.58700
75	17	12.91	0.74217
76	17	19.06	0.32491
77	17	9.70	0.91562
78	17	14.11	0.65909
79	17	20.19	0.26449
80	17	17.12	0.44613
81	17	12.52	0.76795
82	17	21.54	0.20308

83	17	16.03	0.52159
84	17	9.71	0.91546
85	17	18.95	0.33169
86	17	9.47	0.92433
87	17	16.49	0.48932
88	17	12.07	0.79579
89	17	16.34	0.49998
90	17	19.27	0.31340
91	17	16.78	0.46934
92	17	16.90	0.46118
93	17	26.56	0.06477
94	17	18.50	0.35801
95	17	9.79	0.91202
96	17	19.49	0.30120
97	17	13.68	0.68963
98	17	23.43	0.13572
99	17	15.65	0.54874
100	17	29.96	0.02663
Combined P-value for all tests (Using KS method)			0.76049

*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	34.17	0.95745
2	50	62.67	0.10773
3	50	39.96	0.84439
4	50	56.12	0.25618
5	50	75.53	0.01134
6	50	37.67	0.90034
7	50	53.31	0.34801
8	50	45.59	0.65087
9	50	51.28	0.42317
10	50	41.64	0.79406
11	50	39.89	0.84624
12	50	55.01	0.29079
13	50	59.01	0.17946
14	50	51.24	0.42469
15	50	52.13	0.39114
16	50	49.03	0.51214
17	50	46.13	0.62948
18	50	41.27	0.80571
19	50	39.47	0.85764
20	50	43.21	0.74063
21	50	65.22	0.07280
22	50	52.73	0.36898
23	50	55.36	0.27949
24	50	81.28	0.00340
25	50	46.01	0.63414
26	50	34.93	0.94773
27	50	53.43	0.34402
28	50	42.67	0.75940

29	50	40.26	0.83589
30	50	68.46	0.04248
31	50	71.34	0.02535
32	50	51.03	0.43285
33	50	59.77	0.16215
34	50	43.69	0.72301
35	50	60.28	0.15131
36	50	55.76	0.26703
37	50	45.59	0.65096
38	50	68.40	0.04292
39	50	42.67	0.75939
40	50	67.00	0.05439
41	50	51.40	0.41851
42	50	52.51	0.37714
43	50	39.43	0.85863
44	50	66.79	0.05638
45	50	42.73	0.75725
46	50	39.84	0.84767
47	50	49.06	0.51114
48	50	40.13	0.83966
49	50	55.41	0.27795
50	50	44.74	0.68396
51	50	50.23	0.46411
52	50	30.20	0.98799
53	50	57.09	0.22845
54	50	45.09	0.67046
55	50	49.18	0.50616
56	50	50.59	0.45021
57	50	56.17	0.25484
58	50	28.75	0.99314
59	50	58.78	0.18489
60	50	55.15	0.28626
61	50	52.86	0.36420
62	50	69.64	0.03453
63	50	60.85	0.13984
64	50	38.25	0.88773
65	50	53.08	0.35615
66	50	37.26	0.90876
67	50	65.23	0.07261
68	50	62.26	0.11430
69	50	58.92	0.18147
70	50	54.06	0.32227
71	50	41.75	0.79039
72	50	40.87	0.81787
73	50	47.37	0.57939
74	50	58.92	0.18154
75	50	41.03	0.81317
76	50	37.17	0.91069
77	50	57.85	0.20812
78	50	65.80	0.06626
79	50	38.77	0.87544
80	50	50.01	0.47316
81	50	42.62	0.76139
82	50	54.04	0.32287
83	50	39.32	0.86142
84	50	44.92	0.67677

85	50	43.15	0.74282
86	50	61.81	0.12202
87	50	63.21	0.09943
88	50	52.56	0.37506
89	50	47.68	0.56709
90	50	61.59	0.12610
91	50	42.56	0.76323
92	50	33.49	0.96481
93	50	67.16	0.05296
94	50	47.34	0.58062
95	50	54.98	0.29160
96	50	50.44	0.45605
97	50	64.55	0.08089
98	50	70.12	0.03167
99	50	43.16	0.74223
100	50	54.54	0.30612
Combined P-value for all tests			0.64717

*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	8.02	0.78353
2	12	11.08	0.52209
3	12	21.40	0.04485
4	12	13.75	0.31722
5	12	8.19	0.77035
6	12	22.09	0.03653
7	12	11.38	0.49635
8	12	10.39	0.58193
9	12	10.00	0.61600
10	12	20.57	0.05703
11	12	4.26	0.97831
12	12	13.82	0.31249
13	12	13.62	0.32535
14	12	6.59	0.88330
15	12	9.24	0.68268
16	12	14.38	0.27733
17	12	18.83	0.09269
18	12	6.61	0.88252
19	12	11.34	0.49963
20	12	13.46	0.33625
21	12	9.63	0.64811
22	12	15.67	0.20685

23	12	9.35	0.67250
24	12	18.57	0.09932
25	12	7.02	0.85641
26	12	11.12	0.51892
27	12	7.66	0.81100
28	12	21.14	0.04842
29	12	11.04	0.52585
30	12	11.27	0.50615
31	12	7.83	0.79805
32	12	4.22	0.97908
33	12	7.60	0.81536
34	12	12.51	0.40570
35	12	7.73	0.80599
36	12	14.12	0.29296
37	12	7.30	0.83691
38	12	4.36	0.97600
39	12	16.89	0.15370
40	12	15.06	0.23796
41	12	9.16	0.68919
42	12	7.51	0.82235
43	12	10.08	0.60937
44	12	13.61	0.32606
45	12	4.56	0.97109
46	12	16.90	0.15337
47	12	20.74	0.05438
48	12	11.49	0.48759
49	12	9.31	0.67609
50	12	12.13	0.43498
51	12	15.21	0.23002
52	12	12.08	0.43921
53	12	10.66	0.55804
54	12	7.85	0.79682
55	12	16.08	0.18758
56	12	10.66	0.55787
57	12	11.15	0.51632
58	12	3.93	0.98467
59	12	7.80	0.80045
60	12	9.39	0.66937
61	12	5.17	0.95201
62	12	10.77	0.54891
63	12	6.95	0.86074
64	12	15.06	0.23803
65	12	9.51	0.65895
66	12	17.71	0.12487
67	12	12.38	0.41567
68	12	12.29	0.42284
69	12	13.18	0.35611
70	12	11.27	0.50565
71	12	20.85	0.05268
72	12	13.46	0.33640
73	12	7.69	0.80867
74	12	14.63	0.26231
75	12	9.05	0.69870
76	12	5.48	0.93984
77	12	10.25	0.59380
78	12	10.15	0.60302



79	12	9.53	0.65737
80	12	20.40	0.05982
81	12	12.96	0.37215
82	12	20.48	0.05857
83	12	13.18	0.35576
84	12	6.48	0.88997
85	12	15.69	0.20601
86	12	7.90	0.79257
87	12	13.32	0.34651
88	12	18.71	0.09569
89	12	24.00	0.02037
90	12	13.61	0.32653
91	12	7.64	0.81286
92	12	7.50	0.82308
93	12	22.26	0.03466
94	12	5.45	0.94117
95	12	15.22	0.22957
96	12	9.49	0.66074
97	12	11.20	0.51200
98	12	11.75	0.46558
99	12	10.20	0.59815
100	12	13.28	0.34869
Combined P-value for all tests (Using KS method)			0.93992

*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	16.91	0.15318
2	12	5.48	0.93991
3	12	6.13	0.90961
4	12	15.78	0.20170
5	12	11.84	0.45840
6	12	7.46	0.82578
7	12	22.05	0.03698
8	12	11.36	0.49829
9	12	11.07	0.52329
10	12	19.59	0.07517
11	12	16.78	0.15823
12	12	20.06	0.06597
13	12	10.85	0.54219
14	12	12.70	0.39146
15	12	13.98	0.30177
16	12	8.51	0.74426
17	12	8.54	0.74196
18	12	5.61	0.93442
19	12	13.32	0.34621
20	12	11.49	0.48756
21	12	6.02	0.91495
22	12	12.58	0.40048
23	12	10.00	0.61587
24	12	6.87	0.86635

25	12	4.69	0.96763
26	12	6.04	0.91421
27	12	15.10	0.23614
28	12	10.22	0.59707
29	12	14.77	0.25438
30	12	21.52	0.04321
31	12	10.55	0.56764
32	12	13.28	0.34914
33	12	22.43	0.03295
34	12	18.03	0.11469
35	12	13.01	0.36863
36	12	12.52	0.40459
37	12	12.09	0.43823
38	12	9.19	0.68624
39	12	4.58	0.97065
40	12	8.65	0.73221
41	12	7.40	0.82988
42	12	6.63	0.88115
43	12	15.03	0.23953
44	12	10.25	0.59424
45	12	7.51	0.82196
46	12	16.62	0.16453
47	12	9.89	0.62522
48	12	12.07	0.44046
49	12	12.89	0.37698
50	12	7.30	0.83742
51	12	6.72	0.87563
52	12	15.43	0.21873
53	12	9.39	0.66917
54	12	7.85	0.79689
55	12	11.23	0.50910
56	12	3.47	0.99123
57	12	9.81	0.63267
58	12	14.10	0.29448
59	12	6.18	0.90652
60	12	14.73	0.25633
61	12	14.70	0.25807
62	12	7.82	0.79897
63	12	8.41	0.75269
64	12	16.78	0.15801
65	12	13.21	0.35366
66	12	13.81	0.31307
67	12	10.28	0.59124
68	12	7.90	0.79264
69	12	9.11	0.69350
70	12	17.01	0.14912
71	12	6.50	0.88897
72	12	5.95	0.91855
73	12	17.07	0.14701
74	12	13.46	0.33625
75	12	13.73	0.31857
76	12	26.25	0.00989
77	12	7.84	0.79781
78	12	10.89	0.53839
79	12	28.37	0.00488
80	12	19.78	0.07137

81	12	19.27	0.08231
82	12	9.88	0.62675
83	12	9.35	0.67293
84	12	8.76	0.72290
85	12	6.52	0.88783
86	12	15.86	0.19790
87	12	6.56	0.88511
88	12	9.29	0.67802
89	12	5.83	0.92434
90	12	8.60	0.73703
91	12	22.12	0.03622
92	12	8.46	0.74828
93	12	7.20	0.84423
94	12	9.54	0.65595
95	12	11.28	0.50495
96	12	15.94	0.19397
97	12	13.61	0.32640
98	12	10.11	0.60617
99	12	7.34	0.83421
100	12	5.80	0.92578
Combined P-value for all tests (Using KS method)			0.50714

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)	0.85303	1.00000
Opening Score (Dealer)	0.76049	1.00000
Dealer's Final Score	0.64717	1.00000
Player Cards Rank	0.93992	1.00000
Dealer Cards Rank	0.50714	1.00000
<b>Combined P-Value using Holm's Method</b>		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.

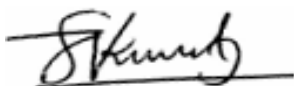
iTech Labs has done limited sanity checks to verify the integrity of the game logs. iTech Labs also maintains a copy of the game logs for verification purposes. There were a large enough number of game records to give the calculations sufficient statistical power.

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:**



---

**Kiren Sreekumar**  
**Principal Consultant**  
**iTech Labs Australia**  
Date: 20 June 2023

**Signed:**



---

**Alvin Rizaldi**  
**Senior Consultant**  
**iTech Labs Australia**  
Date: 20 June 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.

