



## Blackjack Cards Analysis – June 2022

### The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **June 01, 2022 to June 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	17.60	0.41472
2	17	19.91	0.27880
3	17	24.73	0.10096
4	17	15.66	0.54802
5	17	16.54	0.48579
6	17	11.69	0.81863
7	17	15.63	0.54992
8	17	20.29	0.25956
9	17	18.99	0.32899
10	17	15.01	0.59497
11	17	17.61	0.41400
12	17	17.94	0.39281
13	17	17.85	0.39816
14	17	7.59	0.97459
15	17	8.80	0.94629
16	17	11.12	0.85014
17	17	11.07	0.85316
18	17	24.87	0.09756
19	17	13.04	0.73357
20	17	20.95	0.22841
21	17	21.92	0.18779
22	17	8.32	0.95931
23	17	12.29	0.78227

24	17	19.89	0.27977
25	17	20.28	0.26007
26	17	20.95	0.22840
27	17	16.81	0.46699
28	17	10.35	0.88827
29	17	15.03	0.59301
30	17	15.47	0.56165
31	17	23.40	0.13666
32	17	14.00	0.66701
33	17	20.80	0.23546
34	17	22.50	0.16621
35	17	22.21	0.17677
36	17	15.02	0.59374
37	17	17.69	0.40893
38	17	10.60	0.87682
39	17	15.80	0.53822
40	17	16.54	0.48595
41	17	18.86	0.33654
42	17	20.92	0.23009
43	17	15.23	0.57892
44	17	25.76	0.07893
45	17	22.38	0.17053
46	17	29.65	0.02899
47	17	6.61	0.98807
48	17	18.15	0.37916
49	17	12.57	0.76475
50	17	16.11	0.51632
51	17	27.33	0.05341
52	17	11.40	0.83476
53	17	14.86	0.60546
54	17	22.18	0.17793
55	17	13.36	0.71161
56	17	17.54	0.41847
57	17	12.15	0.79125
58	17	13.81	0.68022
59	17	16.81	0.46763
60	17	6.64	0.98780
61	17	8.54	0.95350
62	17	26.88	0.05991
63	17	22.00	0.18455
64	17	7.73	0.97189
65	17	14.97	0.59750
66	17	22.99	0.14944
67	17	18.86	0.33681
68	17	21.82	0.19190
69	17	12.30	0.78160
70	17	14.89	0.60357
71	17	15.93	0.52847
72	17	16.12	0.51540
73	17	22.23	0.17587
74	17	24.61	0.10371
75	17	23.71	0.12748
76	17	15.42	0.56532
77	17	16.65	0.47841
78	17	22.85	0.15411

79	17	26.94	0.05890
80	17	9.62	0.91886
81	17	9.61	0.91915
82	17	19.39	0.30668
83	17	23.12	0.14546
84	17	21.68	0.19740
85	17	19.61	0.29489
86	17	21.07	0.22324
87	17	16.45	0.49214
88	17	18.08	0.38361
89	17	14.72	0.61593
90	17	17.27	0.43636
91	17	18.16	0.37881
92	17	20.87	0.23205
93	17	16.56	0.48436
94	17	21.38	0.20972
95	17	19.64	0.29325
96	17	17.71	0.40733
97	17	11.57	0.82516
98	17	17.75	0.40495
99	17	20.68	0.24106
100	17	19.34	0.30963
Combined P-value for all tests (Using KS method)			0.04869

*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	14.64	0.62134
2	17	11.10	0.85123
3	17	19.78	0.28560
4	17	10.81	0.86635
5	17	20.32	0.25796
6	17	12.73	0.75377
7	17	17.55	0.41756
8	17	16.98	0.45540
9	17	11.06	0.85357
10	17	24.06	0.11773
11	17	11.47	0.83089
12	17	22.70	0.15915
13	17	18.08	0.38382
14	17	18.20	0.37652
15	17	7.72	0.97210
16	17	20.13	0.26778
17	17	20.16	0.26608
18	17	32.00	0.01506
19	17	14.11	0.65943
20	17	10.41	0.88546
21	17	13.05	0.73267
22	17	25.37	0.08663
23	17	15.52	0.55795

24	17	12.73	0.75391
25	17	17.10	0.44794
26	17	16.65	0.47798
27	17	9.27	0.93133
28	17	7.46	0.97680
29	17	8.30	0.95976
30	17	13.41	0.70835
31	17	19.95	0.27656
32	17	20.57	0.24611
33	17	17.65	0.41147
34	17	11.50	0.82937
35	17	21.39	0.20938
36	17	36.16	0.00437
37	17	21.66	0.19796
38	17	23.85	0.12357
39	17	12.98	0.73773
40	17	24.58	0.10455
41	17	5.76	0.99467
42	17	17.60	0.41422
43	17	28.97	0.03479
44	17	15.30	0.57354
45	17	15.97	0.52621
46	17	32.36	0.01356
47	17	17.25	0.43785
48	17	10.23	0.89386
49	17	22.60	0.16286
50	17	18.34	0.36768
51	17	13.84	0.67822
52	17	16.41	0.49491
53	17	18.24	0.37411
54	17	19.08	0.32374
55	17	19.16	0.31956
56	17	19.72	0.28888
57	17	14.41	0.63782
58	17	23.54	0.13248
59	17	14.34	0.64322
60	17	17.01	0.45375
61	17	22.25	0.17531
62	17	23.71	0.12744
63	17	15.43	0.56458
64	17	15.20	0.58142
65	17	11.27	0.84225
66	17	19.35	0.30872
67	17	15.79	0.53851
68	17	18.96	0.33066
69	17	9.24	0.93228
70	17	21.69	0.19701
71	17	12.41	0.77459
72	17	21.86	0.19001
73	17	24.23	0.11336
74	17	27.40	0.05242
75	17	18.59	0.35240
76	17	13.38	0.71053
77	17	14.29	0.64621
78	17	19.24	0.31490

79	17	27.94	0.04570
80	17	14.03	0.66521
81	17	19.71	0.28919
82	17	15.80	0.53832
83	17	16.56	0.48424
84	17	8.43	0.95650
85	17	24.74	0.10077
86	17	15.70	0.54530
87	17	10.77	0.86846
88	17	13.20	0.72286
89	17	14.30	0.64590
90	17	29.84	0.02756
91	17	14.76	0.61265
92	17	15.03	0.59313
93	17	20.97	0.22756
94	17	22.44	0.16833
95	17	10.44	0.88406
96	17	11.36	0.83706
97	17	15.88	0.53254
98	17	17.64	0.41170
99	17	18.65	0.34915
100	17	17.76	0.40430
Combined P-value for all tests (Using KS method)			0.91760

*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	43.50	0.73016
2	50	42.39	0.76910
3	50	47.49	0.57487
4	50	83.38	0.00213
5	50	29.72	0.98993
6	50	42.24	0.77408
7	50	50.14	0.46770
8	50	60.14	0.15426
9	50	41.73	0.79106
10	50	54.07	0.32164
11	50	63.41	0.09639
12	50	35.81	0.93485
13	50	48.98	0.51418
14	50	62.47	0.11087
15	50	35.04	0.94621
16	50	43.18	0.74144
17	50	47.92	0.55705
18	50	58.23	0.19822
19	50	51.25	0.42454
20	50	43.86	0.71692
21	50	53.29	0.34881
22	50	46.92	0.59755
23	50	43.51	0.72982

24	50	48.61	0.52933
25	50	66.08	0.06339
26	50	48.35	0.53979
27	50	38.25	0.88760
28	50	38.38	0.88472
29	50	58.90	0.18195
30	50	46.97	0.59574
31	50	63.00	0.10258
32	50	55.49	0.27541
33	50	54.99	0.29135
34	50	56.86	0.23488
35	50	47.68	0.56679
36	50	69.58	0.03492
37	50	46.74	0.60514
38	50	34.13	0.95790
39	50	47.30	0.58249
40	50	35.57	0.93852
41	50	66.15	0.06265
42	50	44.83	0.68050
43	50	58.06	0.20267
44	50	45.73	0.64529
45	50	46.88	0.59915
46	50	68.14	0.04487
47	50	51.92	0.39880
48	50	48.43	0.53636
49	50	56.77	0.23732
50	50	58.23	0.19821
51	50	45.56	0.65193
52	50	56.35	0.24943
53	50	55.61	0.27176
54	50	47.36	0.57999
55	50	61.10	0.13517
56	50	42.23	0.77439
57	50	53.01	0.35881
58	50	52.24	0.38685
59	50	44.49	0.69339
60	50	79.75	0.00473
61	50	76.43	0.00945
62	50	31.37	0.98188
63	50	78.09	0.00671
64	50	65.76	0.06670
65	50	44.28	0.70112
66	50	43.04	0.74659
67	50	58.37	0.19483
68	50	35.64	0.93753
69	50	69.53	0.03519
70	50	48.12	0.54911
71	50	38.39	0.88435
72	50	53.83	0.33008
73	50	65.09	0.07425
74	50	49.34	0.49993
75	50	37.89	0.89562
76	50	54.45	0.30912
77	50	50.37	0.45868
78	50	41.95	0.78376

79	50	64.01	0.08798
80	50	67.45	0.05044
81	50	43.13	0.74342
82	50	52.05	0.39390
83	50	48.22	0.54524
84	50	56.68	0.23993
85	50	42.37	0.76974
86	50	40.23	0.83687
87	50	53.78	0.33155
88	50	52.32	0.38400
89	50	36.54	0.92250
90	50	49.52	0.49261
91	50	43.92	0.71485
92	50	60.12	0.15473
93	50	52.82	0.36575
94	50	52.20	0.38831
95	50	60.18	0.15348
96	50	49.69	0.48564
97	50	45.30	0.66228
98	50	59.42	0.16988
99	50	43.08	0.74528
100	50	49.62	0.48852
Combined P-value for all tests			0.71381

*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	9.77	0.63581
2	12	9.25	0.68141
3	12	11.85	0.45750
4	12	16.91	0.15295
5	12	6.59	0.88349
6	12	14.42	0.27450
7	12	19.30	0.08148
8	12	9.34	0.67390
9	12	14.58	0.26538
10	12	12.89	0.37745
11	12	9.00	0.70273
12	12	16.05	0.18908
13	12	12.12	0.43642
14	12	4.33	0.97682
15	12	15.68	0.20623

16	12	10.29	0.59088
17	12	9.57	0.65372
18	12	7.59	0.81648
19	12	14.06	0.29687
20	12	13.36	0.34346
21	12	18.13	0.11182
22	12	18.41	0.10374
23	12	8.63	0.73455
24	12	6.27	0.90168
25	12	9.97	0.61890
26	12	6.94	0.86187
27	12	10.93	0.53512
28	12	20.08	0.06563
29	12	6.09	0.91128
30	12	11.86	0.45719
31	12	5.36	0.94504
32	12	7.13	0.84914
33	12	5.38	0.94389
34	12	17.89	0.11922
35	12	8.46	0.74833
36	12	19.15	0.08490
37	12	5.37	0.94455
38	12	19.44	0.07847
39	12	19.21	0.08363
40	12	13.41	0.34030
41	12	11.67	0.47259
42	12	9.49	0.66084
43	12	7.19	0.84466
44	12	13.29	0.34835
45	12	6.66	0.87933
46	12	9.91	0.62426
47	12	16.98	0.15021
48	12	11.84	0.45829
49	12	18.30	0.10684
50	12	17.38	0.13593
51	12	8.63	0.73457
52	12	4.52	0.97201
53	12	13.85	0.31065
54	12	14.26	0.28423
55	12	27.31	0.00698
56	12	17.45	0.13335
57	12	4.10	0.98148
58	12	16.11	0.18615
59	12	7.95	0.78909
60	12	5.47	0.94046
61	12	14.19	0.28885
62	12	13.51	0.33280
63	12	17.09	0.14625
64	12	8.98	0.70465
65	12	15.71	0.20500
66	12	16.37	0.17496
67	12	11.36	0.49814
68	12	9.78	0.63547
69	12	9.85	0.62900
70	12	21.78	0.04008



71	12	7.65	0.81203
72	12	8.78	0.72132
73	12	8.05	0.78129
74	12	22.91	0.02849
75	12	4.52	0.97209
76	12	7.32	0.83569
77	12	7.54	0.81978
78	12	17.98	0.11636
79	12	8.72	0.72666
80	12	15.34	0.22340
81	12	16.47	0.17078
82	12	13.49	0.33450
83	12	12.39	0.41457
84	12	22.97	0.02798
85	12	13.25	0.35128
86	12	14.48	0.27121
87	12	17.64	0.12707
88	12	8.22	0.76749
89	12	23.32	0.02514
90	12	20.16	0.06410
91	12	16.19	0.18263
92	12	15.01	0.24068
93	12	12.07	0.44027
94	12	6.96	0.86044
95	12	5.20	0.95087
96	12	17.88	0.11928
97	12	6.01	0.91581
98	12	11.16	0.51529
99	12	11.86	0.45702
100	12	6.31	0.89944
Combined P-value for all tests (Using KS method)			0.39430

*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	12.36	0.41725
2	12	17.08	0.14675
3	12	17.28	0.13935
4	12	4.58	0.97059
5	12	12.89	0.37690
6	12	5.03	0.95705
7	12	14.57	0.26560
8	12	6.32	0.89893
9	12	17.80	0.12179
10	12	25.38	0.01311
11	12	11.99	0.44610
12	12	8.09	0.77798
13	12	18.53	0.10064
14	12	9.86	0.62786
15	12	5.13	0.95347

16	12	8.60	0.73638
17	12	20.84	0.05272
18	12	10.81	0.54524
19	12	19.61	0.07476
20	12	12.65	0.39520
21	12	9.90	0.62498
22	12	13.14	0.35865
23	12	11.25	0.50743
24	12	6.32	0.89893
25	12	3.36	0.99247
26	12	6.57	0.88486
27	12	6.32	0.89923
28	12	14.28	0.28325
29	12	15.18	0.23191
30	12	10.02	0.61438
31	12	11.19	0.51229
32	12	17.22	0.14134
33	12	7.41	0.82962
34	12	8.12	0.77592
35	12	7.60	0.81578
36	12	13.54	0.33097
37	12	10.00	0.61558
38	12	19.25	0.08256
39	12	14.46	0.27215
40	12	7.50	0.82272
41	12	5.80	0.92586
42	12	12.69	0.39226
43	12	15.68	0.20635
44	12	12.31	0.42087
45	12	13.39	0.34132
46	12	6.32	0.89903
47	12	17.66	0.12643
48	12	10.11	0.60613
49	12	4.83	0.96327
50	12	10.40	0.58089
51	12	8.06	0.78081
52	12	14.01	0.30037
53	12	6.73	0.87512
54	12	12.24	0.42681
55	12	3.06	0.99513
56	12	4.20	0.97953
57	12	7.04	0.85513
58	12	14.75	0.25566
59	12	20.23	0.06286
60	12	8.89	0.71267
61	12	11.51	0.48597
62	12	5.88	0.92212
63	12	15.98	0.19202
64	12	13.13	0.35980
65	12	13.06	0.36488
66	12	5.86	0.92291
67	12	12.58	0.39997
68	12	18.41	0.10386
69	12	7.63	0.81305
70	12	12.03	0.44332

71	12	18.01	0.11547
72	12	11.29	0.50385
73	12	7.55	0.81940
74	12	12.23	0.42757
75	12	10.30	0.58986
76	12	7.63	0.81349
77	12	7.79	0.80144
78	12	18.23	0.10875
79	12	7.43	0.82797
80	12	13.43	0.33886
81	12	11.30	0.50353
82	12	9.46	0.66291
83	12	11.60	0.47868
84	12	9.03	0.70052
85	12	12.83	0.38123
86	12	5.73	0.92925
87	12	11.28	0.50535
88	12	11.22	0.50994
89	12	13.83	0.31145
90	12	16.72	0.16048
91	12	10.50	0.57239
92	12	6.98	0.85897
93	12	20.19	0.06360
94	12	4.39	0.97538
95	12	9.69	0.64313
96	12	8.95	0.70711
97	12	5.84	0.92383
98	12	4.96	0.95946
99	12	11.71	0.46937
100	12	30.15	0.00265
Combined P-value for all tests (Using KS method)			0.19971

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)	0.04869	0.24343
Opening Score (Dealer)	0.91760	1.00000
Dealer's Final Score	0.71381	1.00000
Player Cards Rank	0.39430	1.00000
Dealer Cards Rank	0.19971	0.79883
<b>Combined P-Value using Holm's Method</b>		<b>0.24343</b>

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.

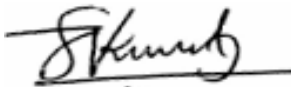
iTech Labs has done limited sanity checks to verify the integrity of the game logs. iTech Labs also maintains a copy of the game logs for verification purposes. There were a large enough number of game records to give the calculations sufficient statistical power.

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: 01 August, 2022

**Signed:**



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**Gyulserian Hyussein**  
**Senior Consultant**  
**iTech Labs Australia**  
Date: 01 August, 2022

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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.