



## Blackjack Cards Analysis – March 2022

### The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **March 01, 2022 to March 31, 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	10.60	0.87672
2	17	27.14	0.05607
3	17	10.52	0.88036
4	17	26.09	0.07288
5	17	20.54	0.24748
6	17	14.54	0.62845
7	17	12.10	0.79410
8	17	18.52	0.35685
9	17	11.60	0.82383
10	17	19.61	0.29442
11	17	25.56	0.08285
12	17	17.99	0.38945
13	17	17.38	0.42902
14	17	18.27	0.37195
15	17	22.75	0.15756
16	17	12.86	0.74559
17	17	43.64	0.00039
18	17	12.45	0.77187
19	17	16.25	0.50596
20	17	10.72	0.87054
21	17	10.65	0.87402
22	17	28.25	0.04212
23	17	8.84	0.94503

24	17	30.35	0.02394
25	17	7.65	0.97341
26	17	16.91	0.46082
27	17	17.79	0.40196
28	17	19.95	0.27702
29	17	19.06	0.32526
30	17	14.77	0.61222
31	17	16.16	0.51231
32	17	23.57	0.13148
33	17	13.22	0.72136
34	17	14.41	0.63824
35	17	13.45	0.70534
36	17	18.46	0.36009
37	17	18.49	0.35869
38	17	8.66	0.95022
39	17	12.77	0.75118
40	17	20.55	0.24725
41	17	23.77	0.12593
42	17	18.66	0.34838
43	17	25.69	0.08031
44	17	14.35	0.64187
45	17	18.70	0.34622
46	17	18.59	0.35262
47	17	16.82	0.46637
48	17	11.51	0.82911
49	17	24.60	0.10393
50	17	20.96	0.22825
51	17	23.48	0.13431
52	17	24.85	0.09821
53	17	19.89	0.28012
54	17	10.22	0.89392
55	17	13.63	0.69294
56	17	24.68	0.10218
57	17	18.81	0.33949
58	17	22.83	0.15489
59	17	17.02	0.45289
60	17	15.88	0.53269
61	17	11.74	0.81590
62	17	23.90	0.12221
63	17	20.53	0.24786
64	17	17.48	0.42244
65	17	22.09	0.18143
66	17	18.22	0.37520
67	17	17.90	0.39503
68	17	8.63	0.95126
69	17	21.76	0.19427
70	17	22.30	0.17355
71	17	23.27	0.14069
72	17	20.70	0.23987
73	17	21.89	0.18911
74	17	5.87	0.99399
75	17	17.19	0.44126
76	17	11.59	0.82427
77	17	12.05	0.79709
78	17	24.71	0.10136

79	17	13.69	0.68916
80	17	10.83	0.86506
81	17	13.18	0.72386
82	17	12.45	0.77245
83	17	11.68	0.81893
84	17	18.31	0.36953
85	17	14.31	0.64533
86	17	11.76	0.81424
87	17	14.87	0.60497
88	17	13.32	0.71477
89	17	16.72	0.47331
90	17	13.93	0.67188
91	17	23.52	0.13295
92	17	22.19	0.17753
93	17	12.87	0.74453
94	17	17.97	0.39055
95	17	12.00	0.80039
96	17	16.82	0.46672
97	17	18.59	0.35285
98	17	10.85	0.86439
99	17	19.62	0.29415
100	17	18.51	0.35724
Combined P-value for all tests (Using KS method)			0.29256

*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	12.28	0.78267
2	17	11.09	0.85177
3	17	18.55	0.35519
4	17	24.18	0.11468
5	17	14.72	0.61561
6	17	22.70	0.15921
7	17	13.38	0.71057
8	17	15.61	0.55158
9	17	16.49	0.48960
10	17	15.91	0.53029
11	17	15.94	0.52810
12	17	20.99	0.22688
13	17	23.36	0.13788
14	17	20.18	0.26504
15	17	11.74	0.81533
16	17	9.14	0.93561
17	17	25.97	0.07506
18	17	22.78	0.15654
19	17	20.37	0.25571
20	17	12.25	0.78482
21	17	25.47	0.08477
22	17	8.25	0.96089
23	17	10.33	0.88910

24	17	16.14	0.51428
25	17	18.79	0.34099
26	17	13.62	0.69374
27	17	27.98	0.04523
28	17	11.88	0.80764
29	17	19.68	0.29090
30	17	20.16	0.26604
31	17	20.58	0.24550
32	17	14.82	0.60827
33	17	18.36	0.36670
34	17	15.16	0.58415
35	17	21.99	0.18497
36	17	19.54	0.29821
37	17	12.89	0.74345
38	17	9.28	0.93097
39	17	7.51	0.97602
40	17	21.25	0.21542
41	17	19.79	0.28494
42	17	21.83	0.19149
43	17	12.29	0.78238
44	17	23.03	0.14822
45	17	19.10	0.32307
46	17	20.08	0.27014
47	17	17.57	0.41666
48	17	16.44	0.49310
49	17	9.46	0.92461
50	17	6.96	0.98408
51	17	21.84	0.19097
52	17	15.06	0.59119
53	17	12.70	0.75634
54	17	18.26	0.37240
55	17	17.70	0.40830
56	17	10.66	0.87351
57	17	16.13	0.51497
58	17	6.99	0.98372
59	17	31.68	0.01650
60	17	14.93	0.60020
61	17	9.54	0.92185
62	17	26.42	0.06706
63	17	22.48	0.16695
64	17	17.20	0.44065
65	17	10.58	0.87773
66	17	18.91	0.33357
67	17	16.75	0.47140
68	17	9.03	0.93926
69	17	16.84	0.46510
70	17	18.20	0.37657
71	17	8.68	0.94963
72	17	15.99	0.52484
73	17	15.60	0.55260
74	17	19.09	0.32335
75	17	15.08	0.58984
76	17	17.57	0.41670
77	17	17.20	0.44099
78	17	12.31	0.78080

79	17	10.32	0.88977
80	17	11.16	0.84829
81	17	24.72	0.10114
82	17	33.45	0.00987
83	17	8.89	0.94354
84	17	20.22	0.26308
85	17	22.33	0.17229
86	17	17.70	0.40777
87	17	10.25	0.89265
88	17	13.63	0.69278
89	17	20.31	0.25869
90	17	11.48	0.83047
91	17	22.01	0.18421
92	17	12.09	0.79442
93	17	14.91	0.60189
94	17	22.14	0.17942
95	17	13.06	0.73241
96	17	15.34	0.57099
97	17	22.92	0.15194
98	17	19.83	0.28287
99	17	15.01	0.59447
100	17	21.11	0.22129
Combined P-value for all tests (Using KS method)			0.87752

*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	31.62	0.98028
2	50	60.21	0.15273
3	50	44.42	0.69579
4	50	53.50	0.34142
5	50	73.57	0.01666
6	50	43.26	0.73860
7	50	58.74	0.18582
8	50	53.31	0.34802
9	50	42.20	0.77542
10	50	37.45	0.90501
11	50	59.76	0.16233
12	50	51.66	0.40885
13	50	85.44	0.00133
14	50	39.61	0.85388
15	50	38.38	0.88458
16	50	62.71	0.10705
17	50	55.09	0.28810
18	50	45.60	0.65035
19	50	67.97	0.04623
20	50	47.97	0.55523
21	50	44.16	0.70573
22	50	46.56	0.61210
23	50	33.10	0.96860

24	50	42.57	0.76296
25	50	53.96	0.32560
26	50	66.35	0.06058
27	50	45.86	0.64014
28	50	65.73	0.06703
29	50	61.05	0.13609
30	50	30.45	0.98683
31	50	37.89	0.89560
32	50	71.75	0.02353
33	50	63.51	0.09501
34	50	44.06	0.70938
35	50	42.04	0.78068
36	50	58.75	0.18566
37	50	60.16	0.15389
38	50	46.58	0.61122
39	50	50.00	0.47336
40	50	50.69	0.44616
41	50	49.31	0.50092
42	50	59.89	0.15956
43	50	29.25	0.99160
44	50	64.48	0.08178
45	50	52.53	0.37642
46	50	67.59	0.04927
47	50	38.20	0.88875
48	50	39.10	0.86719
49	50	60.95	0.13790
50	50	52.99	0.35954
51	50	54.67	0.30173
52	50	42.59	0.76221
53	50	40.38	0.83246
54	50	35.57	0.93859
55	50	56.15	0.25535
56	50	45.02	0.67312
57	50	38.16	0.88975
58	50	40.85	0.81846
59	50	59.03	0.17884
60	50	43.42	0.73305
61	50	54.33	0.31296
62	50	40.31	0.83451
63	50	46.27	0.62401
64	50	41.47	0.79928
65	50	59.63	0.16523
66	50	49.72	0.48450
67	50	41.72	0.79132
68	50	51.22	0.42566
69	50	33.22	0.96752
70	50	59.42	0.17006
71	50	51.35	0.42049
72	50	60.13	0.15454
73	50	77.87	0.00704
74	50	38.74	0.87613
75	50	38.21	0.88853
76	50	54.38	0.31126
77	50	49.40	0.49731
78	50	51.68	0.40790

79	50	42.24	0.77430
80	50	47.00	0.59439
81	50	33.85	0.96097
82	50	40.67	0.82400
83	50	61.06	0.13579
84	50	78.83	0.00575
85	50	49.16	0.50721
86	50	51.20	0.42623
87	50	43.67	0.72380
88	50	56.32	0.25032
89	50	28.12	0.99472
90	50	31.48	0.98118
91	50	50.39	0.45786
92	50	48.31	0.54160
93	50	39.88	0.84665
94	50	43.86	0.71699
95	50	46.88	0.59947
96	50	36.63	0.92077
97	50	56.54	0.24399
98	50	48.22	0.54497
99	50	58.48	0.19216
100	50	66.66	0.05760
Combined P-value for all tests			0.59718

*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	15.22	0.22972
2	12	11.10	0.52060
3	12	6.61	0.88214
4	12	3.95	0.98437
5	12	9.89	0.62519
6	12	13.40	0.34077
7	12	7.13	0.84897
8	12	6.28	0.90109
9	12	3.39	0.99213
10	12	7.48	0.82433
11	12	9.95	0.62035
12	12	19.77	0.07166
13	12	9.14	0.69086
14	12	15.43	0.21862
15	12	13.34	0.34461

16	12	9.78	0.63517
17	12	9.99	0.61664
18	12	9.82	0.63146
19	12	15.07	0.23770
20	12	11.87	0.45611
21	12	12.48	0.40806
22	12	16.99	0.14999
23	12	5.82	0.92492
24	12	14.27	0.28405
25	12	7.44	0.82738
26	12	10.79	0.54713
27	12	8.65	0.73277
28	12	14.18	0.28967
29	12	14.08	0.29558
30	12	4.80	0.96446
31	12	14.26	0.28464
32	12	12.73	0.38882
33	12	7.40	0.83018
34	12	11.85	0.45770
35	12	4.70	0.96722
36	12	11.49	0.48714
37	12	9.10	0.69422
38	12	13.79	0.31443
39	12	16.16	0.18413
40	12	14.34	0.27928
41	12	18.32	0.10635
42	12	7.23	0.84184
43	12	20.16	0.06415
44	12	12.51	0.40531
45	12	17.80	0.12204
46	12	7.63	0.81361
47	12	14.62	0.26267
48	12	8.65	0.73277
49	12	12.89	0.37676
50	12	12.53	0.40432
51	12	8.43	0.75077
52	12	4.94	0.95990
53	12	12.69	0.39174
54	12	5.49	0.93968
55	12	17.71	0.12475
56	12	12.30	0.42192
57	12	13.38	0.34212
58	12	15.06	0.23812
59	12	16.89	0.15369
60	12	14.78	0.25349
61	12	10.85	0.54191
62	12	6.44	0.89211
63	12	13.10	0.36207
64	12	12.23	0.42741
65	12	6.82	0.86916
66	12	9.06	0.69749
67	12	1.91	0.99953
68	12	8.79	0.72107
69	12	18.70	0.09593
70	12	14.02	0.29974



71	12	14.37	0.27768
72	12	19.06	0.08697
73	12	9.61	0.64992
74	12	9.32	0.67507
75	12	14.02	0.29938
76	12	14.99	0.24174
77	12	7.19	0.84510
78	12	12.63	0.39640
79	12	6.56	0.88534
80	12	13.93	0.30549
81	12	14.22	0.28687
82	12	12.80	0.38383
83	12	12.95	0.37275
84	12	6.57	0.88448
85	12	16.69	0.16163
86	12	14.64	0.26194
87	12	14.00	0.30067
88	12	6.81	0.86990
89	12	9.82	0.63146
90	12	5.71	0.92988
91	12	12.02	0.44393
92	12	7.75	0.80420
93	12	10.81	0.54515
94	12	21.08	0.04920
95	12	16.92	0.15247
96	12	12.20	0.42991
97	12	8.02	0.78374
98	12	26.01	0.01069
99	12	12.39	0.41477
100	12	20.31	0.06137
Combined P-value for all tests (Using KS method)			0.49026

*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	17.13	0.14490
2	12	19.32	0.08104
3	12	11.17	0.51459
4	12	7.14	0.84821
5	12	9.80	0.63377
6	12	11.35	0.49940
7	12	12.80	0.38366
8	12	9.89	0.62548
9	12	8.02	0.78379
10	12	13.53	0.33146
11	12	8.88	0.71336
12	12	8.46	0.74830
13	12	10.69	0.55603
14	12	21.85	0.03919
15	12	13.70	0.32017

16	12	10.09	0.60848
17	12	4.74	0.96600
18	12	13.98	0.30210
19	12	9.99	0.61719
20	12	11.34	0.50000
21	12	7.33	0.83478
22	12	7.16	0.84676
23	12	5.21	0.95045
24	12	6.25	0.90274
25	12	3.69	0.98842
26	12	7.61	0.81463
27	12	11.21	0.51072
28	12	14.37	0.27756
29	12	8.15	0.77366
30	12	9.49	0.66090
31	12	14.17	0.28992
32	12	7.10	0.85115
33	12	9.95	0.62051
34	12	13.87	0.30924
35	12	8.60	0.73626
36	12	5.25	0.94899
37	12	5.69	0.93077
38	12	15.29	0.22590
39	12	18.43	0.10329
40	12	7.45	0.82619
41	12	12.68	0.39253
42	12	18.02	0.11505
43	12	20.87	0.05231
44	12	12.96	0.37181
45	12	6.77	0.87232
46	12	12.64	0.39597
47	12	16.10	0.18692
48	12	24.21	0.01906
49	12	12.72	0.39009
50	12	14.49	0.27029
51	12	14.29	0.28230
52	12	14.67	0.26014
53	12	11.66	0.47301
54	12	19.42	0.07896
55	12	9.93	0.62241
56	12	10.56	0.56665
57	12	19.95	0.06813
58	12	15.16	0.23297
59	12	17.51	0.13140
60	12	11.69	0.47069
61	12	12.22	0.42793
62	12	19.65	0.07404
63	12	19.93	0.06842
64	12	4.41	0.97474
65	12	6.65	0.87956
66	12	8.57	0.73914
67	12	9.71	0.64121
68	12	15.33	0.22399
69	12	16.81	0.15672
70	12	8.59	0.73788

71	12	18.86	0.09186
72	12	13.65	0.32369
73	12	15.70	0.20533
74	12	9.25	0.68121
75	12	11.75	0.46625
76	12	9.82	0.63153
77	12	17.40	0.13518
78	12	18.11	0.11233
79	12	13.09	0.36286
80	12	12.94	0.37355
81	12	13.30	0.34747
82	12	14.50	0.26965
83	12	11.45	0.49101
84	12	8.04	0.78239
85	12	17.29	0.13897
86	12	11.98	0.44760
87	12	7.49	0.82337
88	12	8.20	0.76917
89	12	9.74	0.63836
90	12	9.53	0.65674
91	12	10.67	0.55761
92	12	14.05	0.29741
93	12	19.24	0.08288
94	12	16.07	0.18800
95	12	23.08	0.02705
96	12	12.44	0.41103
97	12	6.84	0.86807
98	12	20.01	0.06689
99	12	9.41	0.66787
100	12	9.25	0.68110
Combined P-value for all tests (Using KS method)			0.92540

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)	0.29256	1.00000
Opening Score (Dealer)	0.87752	1.00000
Dealer's Final Score	0.59718	1.00000
Player Cards Rank	0.49026	1.00000
Dealer Cards Rank	0.92540	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.

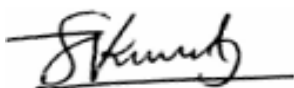
iTech Labs has done limited sanity checks to verify the integrity of the game logs. iTech Labs also maintains a copy of the game logs for verification purposes. There were a large enough number of game records to give the calculations sufficient statistical power.

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.

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**Signed:**



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**Kiren Sreekumar**  
**Principal Consultant**  
**iTech Labs Australia**  
Date: 29 April, 2022

**Signed:**



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**Gyulserian Hyussein**  
**Senior Consultant**  
**iTech Labs Australia**  
Date: 29 April, 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.