



## Blackjack Cards Analysis – September 2021

### The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **September 01, 2021 to September 30, 2021** 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	15.21	0.58009
2	17	20.47	0.25111
3	17	22.01	0.18423
4	17	16.41	0.49467
5	17	12.12	0.79274
6	17	10.70	0.87160
7	17	17.68	0.40956
8	17	27.80	0.04736
9	17	22.14	0.17950
10	17	26.09	0.07282
11	17	9.22	0.93304
12	17	22.88	0.15315
13	17	22.96	0.15056
14	17	23.31	0.13947
15	17	8.27	0.96048
16	17	24.20	0.11423
17	17	13.33	0.71389
18	17	10.48	0.88230
19	17	14.75	0.61354
20	17	22.44	0.16832
21	17	17.79	0.40193
22	17	11.23	0.84459
23	17	14.98	0.59688

24	17	12.36	0.77812
25	17	32.78	0.01201
26	17	27.06	0.05726
27	17	26.61	0.06401
28	17	11.98	0.80109
29	17	22.29	0.17369
30	17	10.89	0.86207
31	17	14.55	0.62762
32	17	9.19	0.93405
33	17	13.67	0.69050
34	17	13.25	0.71962
35	17	18.20	0.37620
36	17	15.16	0.58410
37	17	14.68	0.61845
38	17	17.71	0.40759
39	17	9.05	0.93880
40	17	22.54	0.16471
41	17	15.59	0.55277
42	17	16.81	0.46712
43	17	14.32	0.64415
44	17	14.46	0.63452
45	17	15.20	0.58115
46	17	20.25	0.26178
47	17	15.76	0.54094
48	17	15.07	0.59062
49	17	23.78	0.12543
50	17	19.36	0.30806
51	17	23.20	0.14287
52	17	14.50	0.63113
53	17	15.68	0.54681
54	17	7.90	0.96865
55	17	12.74	0.75320
56	17	21.63	0.19927
57	17	29.20	0.03275
58	17	11.31	0.84002
59	17	16.99	0.45506
60	17	13.36	0.71153
61	17	12.01	0.79969
62	17	16.26	0.50577
63	17	11.89	0.80669
64	17	7.17	0.98121
65	17	15.53	0.55730
66	17	15.37	0.56880
67	17	20.45	0.25180
68	17	10.26	0.89245
69	17	24.81	0.09901
70	17	25.42	0.08574
71	17	20.97	0.22750
72	17	14.22	0.65133
73	17	17.37	0.42939
74	17	12.11	0.79325
75	17	11.80	0.81198
76	17	15.35	0.57015
77	17	24.12	0.11624
78	17	15.69	0.54568

79	17	22.05	0.18281
80	17	20.07	0.27065
81	17	11.38	0.83626
82	17	14.49	0.63193
83	17	14.94	0.60016
84	17	20.84	0.23359
85	17	11.33	0.83871
86	17	20.80	0.23531
87	17	27.06	0.05715
88	17	15.48	0.56097
89	17	16.06	0.51945
90	17	15.20	0.58129
91	17	16.54	0.48622
92	17	17.35	0.43065
93	17	19.99	0.27498
94	17	9.01	0.93996
95	17	12.13	0.79233
96	17	23.38	0.13742
97	17	9.02	0.93979
98	17	17.33	0.43217
99	17	13.35	0.71217
100	17	12.83	0.74728
Combined P-value for all tests (Using KS method)			0.51192

*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	13.39	0.70946
2	17	10.11	0.89904
3	17	27.11	0.05641
4	17	21.38	0.20982
5	17	23.57	0.13153
6	17	24.93	0.09638
7	17	10.17	0.89634
8	17	27.44	0.05186
9	17	22.85	0.15406
10	17	14.69	0.61770
11	17	18.54	0.35546
12	17	26.70	0.06267
13	17	16.08	0.51784
14	17	19.08	0.32388
15	17	9.28	0.93110
16	17	16.08	0.51794
17	17	27.78	0.04755
18	17	13.41	0.70856
19	17	21.67	0.19762
20	17	8.13	0.96367
21	17	10.80	0.86694
22	17	15.86	0.53401
23	17	26.08	0.07300

24	17	14.14	0.65682
25	17	13.67	0.69050
26	17	11.30	0.84046
27	17	12.08	0.79541
28	17	29.14	0.03324
29	17	18.55	0.35509
30	17	18.75	0.34317
31	17	17.92	0.39392
32	17	15.65	0.54898
33	17	26.26	0.06987
34	17	22.60	0.16262
35	17	14.21	0.65238
36	17	15.68	0.54680
37	17	15.74	0.54258
38	17	20.47	0.25066
39	17	11.88	0.80732
40	17	11.29	0.84109
41	17	28.77	0.03675
42	17	10.99	0.85712
43	17	19.04	0.32615
44	17	26.57	0.06470
45	17	13.49	0.70273
46	17	17.12	0.44634
47	17	21.98	0.18564
48	17	22.41	0.16943
49	17	13.88	0.67558
50	17	14.36	0.64137
51	17	8.45	0.95605
52	17	9.03	0.93934
53	17	14.40	0.63880
54	17	13.27	0.71824
55	17	23.79	0.12515
56	17	13.77	0.68312
57	17	19.38	0.30740
58	17	23.55	0.13223
59	17	16.53	0.48685
60	17	4.94	0.99794
61	17	14.10	0.66006
62	17	19.77	0.28614
63	17	11.27	0.84207
64	17	12.70	0.75608
65	17	14.59	0.62465
66	17	12.59	0.76315
67	17	17.55	0.41756
68	17	13.60	0.69551
69	17	22.40	0.16998
70	17	13.19	0.72308
71	17	22.20	0.17703
72	17	18.16	0.37897
73	17	16.04	0.52120
74	17	17.61	0.41368
75	17	31.66	0.01659
76	17	14.86	0.60592
77	17	15.41	0.56632
78	17	17.23	0.43891

79	17	9.67	0.91696
80	17	19.65	0.29273
81	17	16.88	0.46250
82	17	11.31	0.83999
83	17	29.28	0.03207
84	17	22.40	0.16991
85	17	16.35	0.49891
86	17	12.45	0.77244
87	17	18.72	0.34510
88	17	18.76	0.34268
89	17	14.85	0.60645
90	17	19.70	0.28984
91	17	30.19	0.02503
92	17	23.86	0.12321
93	17	10.47	0.88277
94	17	24.58	0.10442
95	17	14.69	0.61757
96	17	18.37	0.36590
97	17	17.94	0.39291
98	17	24.98	0.09519
99	17	15.38	0.56830
100	17	15.86	0.53404
Combined P-value for all tests (Using KS method)			0.74756

*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	47.76	0.56393
2	50	54.23	0.31634
3	50	58.62	0.18868
4	50	46.83	0.60155
5	50	56.20	0.25385
6	50	52.50	0.37734
7	50	47.76	0.56364
8	50	66.52	0.05892
9	50	40.09	0.84072
10	50	47.74	0.56468
11	50	51.76	0.40496
12	50	49.31	0.50082
13	50	56.03	0.25910
14	50	36.06	0.93074
15	50	48.59	0.53026
16	50	55.56	0.27321
17	50	55.31	0.28114
18	50	72.47	0.02055
19	50	54.04	0.32296
20	50	66.93	0.05503
21	50	52.12	0.39149
22	50	52.33	0.38380
23	50	42.58	0.76263

24	50	46.54	0.61311
25	50	65.86	0.06570
26	50	59.33	0.17196
27	50	73.49	0.01692
28	50	44.32	0.69977
29	50	49.21	0.50522
30	50	43.90	0.71535
31	50	48.20	0.54609
32	50	51.72	0.40660
33	50	34.17	0.95741
34	50	36.99	0.91413
35	50	67.81	0.04749
36	50	46.82	0.60171
37	50	53.84	0.32977
38	50	79.49	0.00500
39	50	40.30	0.83488
40	50	50.31	0.46126
41	50	44.42	0.69606
42	50	43.99	0.71220
43	50	39.12	0.86668
44	50	66.53	0.05881
45	50	47.42	0.57759
46	50	58.47	0.19232
47	50	38.81	0.87428
48	50	25.03	0.99879
49	50	47.97	0.55509
50	50	54.41	0.31050
51	50	65.29	0.07193
52	50	43.38	0.73438
53	50	63.45	0.09587
54	50	55.82	0.26543
55	50	51.42	0.41782
56	50	58.48	0.19219
57	50	46.77	0.60359
58	50	50.58	0.45046
59	50	60.78	0.14123
60	50	53.19	0.35229
61	50	64.32	0.08388
62	50	59.00	0.17958
63	50	50.33	0.46034
64	50	51.66	0.40873
65	50	49.87	0.47858
66	50	39.19	0.86485
67	50	38.50	0.88178
68	50	52.16	0.39007
69	50	33.64	0.96329
70	50	38.76	0.87561
71	50	49.83	0.48032
72	50	40.66	0.82433
73	50	63.94	0.08895
74	50	56.90	0.23369
75	50	35.35	0.94181
76	50	56.47	0.24615
77	50	63.34	0.09745
78	50	60.45	0.14788

79	50	46.61	0.61025
80	50	43.74	0.72149
Combined P-value for all tests			0.25369

**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	9.73	0.63991
2	12	6.44	0.89228
3	12	7.12	0.84983
4	12	13.98	0.30196
5	12	9.01	0.70214
6	12	11.63	0.47583
7	12	11.04	0.52529
8	12	13.92	0.30598
9	12	13.18	0.35575
10	12	16.27	0.17902
11	12	15.99	0.19180
12	12	5.98	0.91721
13	12	10.47	0.57476
14	12	5.31	0.94694
15	12	7.28	0.83837
16	12	6.58	0.88434
17	12	4.96	0.95918
18	12	17.99	0.11585
19	12	12.36	0.41737
20	12	17.19	0.14244
21	12	15.24	0.22836
22	12	2.88	0.99631
23	12	12.37	0.41616
24	12	14.43	0.27393
25	12	11.14	0.51730
26	12	17.43	0.13402
27	12	7.89	0.79397
28	12	10.16	0.60207
29	12	26.30	0.00973
30	12	4.81	0.96410
31	12	20.93	0.05145
32	12	16.58	0.16629
33	12	15.60	0.21037
34	12	9.53	0.65673
35	12	18.99	0.08869

36	12	10.17	0.60115
37	12	10.97	0.53108
38	12	11.94	0.45035
39	12	7.12	0.84983
40	12	11.03	0.52618
41	12	14.20	0.28787
42	12	13.67	0.32204
43	12	3.01	0.99545
44	12	12.25	0.42550
45	12	20.85	0.05255
46	12	14.68	0.25927
47	12	5.59	0.93520
48	12	17.25	0.14058
49	12	8.24	0.76572
50	12	6.21	0.90532
51	12	16.68	0.16214
52	12	27.92	0.00569
53	12	10.08	0.60915
54	12	12.89	0.37709
55	12	10.03	0.61333
56	12	13.83	0.31196
57	12	17.90	0.11878
58	12	9.28	0.67919
59	12	8.66	0.73197
60	12	12.63	0.39683
61	12	5.94	0.91890
62	12	5.86	0.92312
63	12	9.54	0.65659
64	12	11.73	0.46735
65	12	13.31	0.34689
66	12	22.82	0.02931
67	12	18.39	0.10438
68	12	6.87	0.86630
69	12	16.30	0.17786
70	12	8.50	0.74491
71	12	14.31	0.28127
72	12	15.56	0.21226
73	12	13.72	0.31881
74	12	12.44	0.41074
75	12	7.95	0.78869
76	12	12.69	0.39225
77	12	24.36	0.01814
78	12	12.79	0.38414
79	12	21.96	0.03793
80	12	5.37	0.94457
81	12	8.71	0.72762
82	12	8.25	0.76503
83	12	9.35	0.67319
84	12	17.86	0.11986
85	12	13.74	0.31795
86	12	17.12	0.14500
87	12	13.27	0.34994
88	12	18.58	0.09919
89	12	4.17	0.98023



90	12	4.65	0.96872
91	12	17.88	0.11932
92	12	11.71	0.46949
93	12	6.79	0.87098
94	12	5.53	0.93782
95	12	13.98	0.30214
96	12	17.84	0.12068
97	12	11.64	0.47484
98	12	13.47	0.33608
99	12	17.24	0.14092
100	12	16.51	0.16891
Combined P-value for all tests (Using KS method)			0.45618

*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	11.33	0.50111
2	12	6.62	0.88183
3	12	6.16	0.90797
4	12	15.32	0.22440
5	12	4.89	0.96166
6	12	12.29	0.42304
7	12	9.01	0.70244
8	12	12.36	0.41724
9	12	3.28	0.99320
10	12	7.72	0.80685
11	12	11.33	0.50080
12	12	13.96	0.30323
13	12	11.08	0.52222
14	12	9.31	0.67655
15	12	18.92	0.09059
16	12	9.32	0.67526
17	12	8.70	0.72791
18	12	8.36	0.75645
19	12	6.12	0.90993
20	12	6.76	0.87291
21	12	4.32	0.97698
22	12	18.74	0.09498
23	12	5.47	0.94058
24	12	8.00	0.78549
25	12	17.44	0.13388
26	12	24.21	0.01905
27	12	6.97	0.85933
28	12	7.81	0.80010
29	12	12.55	0.40236
30	12	4.88	0.96189
31	12	11.81	0.46136
32	12	3.92	0.98482
33	12	9.33	0.67430
34	12	6.05	0.91337

35	12	12.06	0.44067
36	12	7.32	0.83594
37	12	25.82	0.01138
38	12	9.78	0.63517
39	12	6.82	0.86926
40	12	7.66	0.81144
41	12	14.63	0.26249
42	12	20.74	0.05427
43	12	6.91	0.86321
44	12	7.96	0.78842
45	12	6.10	0.91119
46	12	14.25	0.28525
47	12	13.84	0.31103
48	12	11.21	0.51120
49	12	10.39	0.58218
50	12	13.88	0.30827
51	12	11.12	0.51839
52	12	13.54	0.33096
53	12	9.55	0.65507
54	12	12.53	0.40407
55	12	17.57	0.12945
56	12	11.84	0.45902
57	12	8.67	0.73087
58	12	6.20	0.90569
59	12	10.15	0.60239
60	12	18.47	0.10219
61	12	11.76	0.46486
62	12	11.34	0.50022
63	12	16.30	0.17800
64	12	3.00	0.99551
65	12	12.05	0.44197
66	12	13.75	0.31722
67	12	17.41	0.13475
68	12	21.64	0.04172
69	12	6.98	0.85897
70	12	22.55	0.03180
71	12	11.22	0.50983
72	12	12.51	0.40556
73	12	7.92	0.79170
74	12	11.85	0.45796
75	12	12.62	0.39689
76	12	11.35	0.49940
77	12	6.85	0.86740
78	12	16.10	0.18689
79	12	5.34	0.94584
80	12	10.51	0.57111
81	12	6.32	0.89929
82	12	13.13	0.35977
83	12	8.93	0.70866
84	12	5.55	0.93721
85	12	12.49	0.40681
86	12	15.92	0.19507
87	12	9.77	0.63631
88	12	13.74	0.31787
89	12	7.08	0.85227

90	12	8.15	0.77360
91	12	11.74	0.46699
92	12	8.57	0.73899
93	12	14.64	0.26173
94	12	9.55	0.65507
95	12	8.08	0.77849
96	12	13.89	0.30785
97	12	10.10	0.60752
98	12	17.03	0.14841
99	12	5.01	0.95775
100	12	5.90	0.92097
Combined P-value for all tests (Using KS method)			0.07337

*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.

<b>Combination of p-values using Holm's Method</b>		
<b>Test</b>	<b>P-Value</b>	<b>P-Adjusted</b>
Opening Score (Player)	0.51192	1.00000
Opening Score (Dealer)	0.74756	1.00000
Dealer's Final Score	0.25369	1.00000
Player Cards Rank	0.45618	1.00000
Dealer Cards Rank	0.07337	0.36683
<b>Combined P-Value using Holm's Method</b>		0.36683

*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.

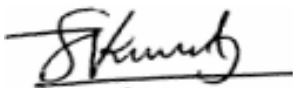
iTech Labs has done limited sanity checks to verify the integrity of the game logs. iTech Labs also maintains a copy of the game logs for verification purposes. There were a large enough number of game records to give the calculations sufficient statistical power.

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: 04 January, 2022

**Signed:**



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**Gyulserian Hyssein**  
**Senior Consultant**  
**iTech Labs Australia**  
Date: 04 January, 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.

