



Blackjack Cards Analysis – August 2022

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **August 01, 2022 to August 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	21.77	0.19360
2	17	34.61	0.00699
3	17	23.58	0.13119
4	17	15.08	0.58986
5	17	7.57	0.97493
6	17	16.20	0.50999
7	17	21.17	0.21894
8	17	11.65	0.82110
9	17	17.33	0.43230
10	17	21.71	0.19594
11	17	21.44	0.20725
12	17	16.29	0.50340
13	17	21.56	0.20219
14	17	18.60	0.35217
15	17	19.84	0.28237
16	17	17.55	0.41745
17	17	16.71	0.47451
18	17	10.56	0.87844
19	17	14.63	0.62228
20	17	19.77	0.28635
21	17	12.41	0.77475
22	17	16.81	0.46741
23	17	6.76	0.98643

24	17	15.05	0.59178
25	17	16.89	0.46164
26	17	7.66	0.97337
27	17	15.01	0.59447
28	17	10.95	0.85923
29	17	17.28	0.43535
30	17	18.97	0.33051
31	17	18.01	0.38823
32	17	16.82	0.46667
33	17	27.01	0.05785
34	17	17.11	0.44682
35	17	17.74	0.40515
36	17	12.53	0.76700
37	17	9.02	0.93963
38	17	18.05	0.38577
39	17	15.56	0.55488
40	17	20.24	0.26221
41	17	14.88	0.60437
42	17	14.93	0.60057
43	17	20.51	0.24875
44	17	25.40	0.08610
45	17	26.84	0.06040
46	17	15.73	0.54307
47	17	9.69	0.91608
48	17	17.03	0.45261
49	17	9.24	0.93242
50	17	8.99	0.94063
51	17	21.77	0.19368
52	17	16.25	0.50615
53	17	12.64	0.76023
54	17	21.42	0.20827
55	17	23.50	0.13363
56	17	14.28	0.64714
57	17	14.20	0.65287
58	17	22.83	0.15485
59	17	20.79	0.23570
60	17	38.33	0.00222
61	17	20.04	0.27210
62	17	10.42	0.88501
63	17	26.90	0.05958
64	17	18.41	0.36367
65	17	17.24	0.43832
66	17	22.56	0.16415
67	17	14.28	0.64736
68	17	15.17	0.58330
69	17	15.57	0.55463
70	17	14.01	0.66623
71	17	12.83	0.74736
72	17	20.03	0.27285
73	17	16.93	0.45879
74	17	13.28	0.71740
75	17	20.09	0.26945
76	17	13.86	0.67720
77	17	11.07	0.85291
78	17	20.34	0.25730

79	17	25.08	0.09294
80	17	15.04	0.59295
81	17	13.92	0.67261
82	17	10.09	0.90000
83	17	11.98	0.80155
84	17	22.04	0.18331
85	17	15.98	0.52543
86	17	14.97	0.59777
87	17	19.20	0.31727
88	17	12.14	0.79148
89	17	20.92	0.22985
90	17	13.86	0.67668
91	17	21.85	0.19065
92	17	16.62	0.48069
93	17	14.25	0.64917
94	17	13.03	0.73418
95	17	15.11	0.58733
96	17	7.05	0.98287
97	17	23.10	0.14590
98	17	13.38	0.71039
99	17	22.68	0.16012
100	17	20.68	0.24088
Combined P-value for all tests (Using KS method)			0.48241

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	28.33	0.04125
2	17	16.82	0.46633
3	17	9.87	0.90913
4	17	16.11	0.51619
5	17	15.75	0.54153
6	17	23.13	0.14512
7	17	21.77	0.19388
8	17	20.88	0.23157
9	17	16.03	0.52169
10	17	21.62	0.19982
11	17	12.18	0.78883
12	17	16.50	0.48848
13	17	29.93	0.02688
14	17	25.81	0.07807
15	17	11.90	0.80631
16	17	26.41	0.06724
17	17	15.60	0.55254
18	17	16.64	0.47885
19	17	22.48	0.16689
20	17	23.69	0.12817
21	17	14.32	0.64417
22	17	10.37	0.88741
23	17	19.27	0.31319

24	17	14.46	0.63416
25	17	31.26	0.01855
26	17	20.59	0.24496
27	17	21.68	0.19732
28	17	13.82	0.67982
29	17	18.80	0.34039
30	17	11.41	0.83456
31	17	18.88	0.33568
32	17	12.28	0.78272
33	17	20.36	0.25618
34	17	22.50	0.16629
35	17	16.21	0.50891
36	17	15.35	0.57057
37	17	18.81	0.33970
38	17	10.61	0.87629
39	17	17.37	0.42985
40	17	12.52	0.76784
41	17	10.18	0.89591
42	17	6.45	0.98960
43	17	26.75	0.06186
44	17	21.74	0.19500
45	17	17.52	0.41988
46	17	15.75	0.54138
47	17	18.72	0.34488
48	17	14.27	0.64760
49	17	21.79	0.19308
50	17	9.75	0.91396
51	17	11.66	0.82009
52	17	11.21	0.84554
53	17	8.80	0.94640
54	17	9.34	0.92888
55	17	9.51	0.92279
56	17	19.90	0.27947
57	17	15.64	0.54971
58	17	15.99	0.52465
59	17	18.09	0.38349
60	17	24.64	0.10317
61	17	14.52	0.62995
62	17	17.06	0.45037
63	17	8.53	0.95399
64	17	19.50	0.30080
65	17	20.08	0.27025
66	17	14.21	0.65198
67	17	15.49	0.56009
68	17	22.43	0.16856
69	17	17.80	0.40176
70	17	12.34	0.77882
71	17	15.83	0.53572
72	17	13.48	0.70331
73	17	21.36	0.21045
74	17	28.66	0.03782
75	17	24.09	0.11694
76	17	13.76	0.68427
77	17	11.21	0.84519
78	17	12.93	0.74116

79	17	23.43	0.13587
80	17	18.20	0.37663
81	17	11.51	0.82914
82	17	21.72	0.19554
83	17	13.32	0.71483
84	17	17.46	0.42379
85	17	26.37	0.06792
86	17	21.86	0.19007
87	17	17.29	0.43470
88	17	5.62	0.99541
89	17	15.02	0.59373
90	17	7.77	0.97119
91	17	27.29	0.05390
92	17	9.10	0.93710
93	17	10.02	0.90256
94	17	21.97	0.18605
95	17	13.77	0.68318
96	17	21.63	0.19927
97	17	16.27	0.50479
98	17	25.19	0.09063
99	17	14.45	0.63472
100	17	9.99	0.90395
Combined P-value for all tests (Using KS method)			0.85119

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	46.84	0.60113
2	50	54.19	0.31762
3	50	56.11	0.25651
4	50	39.58	0.85466
5	50	43.26	0.73871
6	50	53.49	0.34182
7	50	45.23	0.66492
8	50	26.49	0.99747
9	50	55.25	0.28307
10	50	38.13	0.89025
11	50	56.09	0.25708
12	50	47.32	0.58155
13	50	51.44	0.41700
14	50	39.13	0.86631
15	50	54.16	0.31857
16	50	63.71	0.09206
17	50	57.20	0.22546
18	50	66.42	0.05989
19	50	54.72	0.30020
20	50	49.55	0.49152
21	50	57.45	0.21875
22	50	50.46	0.45532
23	50	45.51	0.65387

24	50	36.38	0.92522
25	50	49.32	0.50052
26	50	41.94	0.78416
27	50	61.23	0.13258
28	50	59.20	0.17486
29	50	62.41	0.11187
30	50	38.84	0.87362
31	50	50.71	0.44551
32	50	30.71	0.98554
33	50	49.23	0.50432
34	50	51.63	0.41001
35	50	46.03	0.63348
36	50	40.51	0.82872
37	50	62.73	0.10680
38	50	66.23	0.06177
39	50	59.25	0.17389
40	50	41.02	0.81344
41	50	64.53	0.08112
42	50	56.83	0.23574
43	50	35.41	0.94090
44	50	61.32	0.13088
45	50	40.81	0.81962
46	50	73.38	0.01727
47	50	58.29	0.19693
48	50	49.46	0.49504
49	50	43.17	0.74193
50	50	51.86	0.40133
51	50	35.69	0.93667
52	50	61.42	0.12909
53	50	56.21	0.25374
54	50	52.46	0.37879
55	50	38.48	0.88230
56	50	57.14	0.22697
57	50	46.63	0.60931
58	50	52.81	0.36588
59	50	55.63	0.27127
60	50	39.37	0.86021
61	50	53.56	0.33942
62	50	66.39	0.06026
63	50	77.18	0.00811
64	50	57.52	0.21687
65	50	46.39	0.61906
66	50	53.33	0.34731
67	50	58.98	0.18003
68	50	35.40	0.94104
69	50	50.22	0.46454
70	50	44.14	0.70666
71	50	38.99	0.86991
72	50	34.85	0.94892
73	50	55.96	0.26106
74	50	43.97	0.71290
75	50	35.62	0.93781
76	50	36.73	0.91892
77	50	65.65	0.06789
78	50	50.98	0.43490

79	50	64.65	0.07968
80	50	47.60	0.57016
81	50	47.88	0.55868
82	50	56.48	0.24570
83	50	56.85	0.23513
84	50	53.73	0.33357
85	50	45.28	0.66300
86	50	69.32	0.03653
87	50	46.59	0.61089
88	50	75.58	0.01123
89	50	57.38	0.22059
90	50	35.71	0.93645
91	50	38.37	0.88496
92	50	46.66	0.60808
93	50	41.74	0.79071
94	50	48.09	0.55020
95	50	57.00	0.23083
96	50	43.61	0.72614
97	50	36.47	0.92368
98	50	32.66	0.97255
99	50	52.33	0.38375
100	50	57.89	0.20708
Combined P-value for all tests			0.65005

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	11.76	0.46476
2	12	18.15	0.11107
3	12	10.42	0.57882
4	12	16.97	0.15068
5	12	8.32	0.75936
6	12	14.64	0.26149
7	12	9.28	0.67846
8	12	7.46	0.82603
9	12	10.04	0.61289
10	12	12.37	0.41649
11	12	11.67	0.47256
12	12	24.58	0.01694
13	12	9.50	0.65980
14	12	16.77	0.15845
15	12	18.72	0.09542

16	12	11.12	0.51835
17	12	13.12	0.36054
18	12	11.27	0.50617
19	12	10.11	0.60594
20	12	4.47	0.97336
21	12	17.47	0.13276
22	12	7.78	0.80201
23	12	7.83	0.79839
24	12	5.12	0.95377
25	12	13.95	0.30378
26	12	16.90	0.15326
27	12	7.57	0.81755
28	12	5.85	0.92334
29	12	22.54	0.03185
30	12	13.45	0.33750
31	12	6.90	0.86391
32	12	8.60	0.73653
33	12	15.73	0.20403
34	12	24.15	0.01938
35	12	2.20	0.99902
36	12	15.25	0.22794
37	12	9.03	0.69995
38	12	16.92	0.15278
39	12	13.12	0.36068
40	12	13.55	0.33042
41	12	10.38	0.58301
42	12	7.19	0.84459
43	12	7.24	0.84115
44	12	11.95	0.44978
45	12	22.64	0.03097
46	12	10.70	0.55480
47	12	5.73	0.92895
48	12	11.02	0.52697
49	12	8.09	0.77830
50	12	19.47	0.07790
51	12	13.83	0.31193
52	12	10.16	0.60227
53	12	9.48	0.66128
54	12	14.34	0.27960
55	12	13.20	0.35481
56	12	15.89	0.19652
57	12	8.13	0.77521
58	12	21.91	0.03853
59	12	7.20	0.84444
60	12	6.64	0.88055
61	12	11.46	0.48965
62	12	11.69	0.47052
63	12	8.55	0.74040
64	12	13.48	0.33501
65	12	14.56	0.26659
66	12	13.14	0.35867
67	12	8.73	0.72568
68	12	16.05	0.18874
69	12	3.76	0.98735
70	12	18.54	0.10013

71	12	11.17	0.51477
72	12	15.43	0.21872
73	12	24.61	0.01678
74	12	17.12	0.14519
75	12	10.40	0.58121
76	12	8.55	0.74067
77	12	9.03	0.70032
78	12	7.30	0.83706
79	12	9.80	0.63353
80	12	7.54	0.81990
81	12	11.33	0.50056
82	12	7.79	0.80131
83	12	9.42	0.66703
84	12	12.87	0.37889
85	12	9.63	0.64804
86	12	11.50	0.48631
87	12	8.85	0.71545
88	12	7.60	0.81560
89	12	12.77	0.38572
90	12	14.96	0.24383
91	12	20.81	0.05331
92	12	13.72	0.31886
93	12	11.49	0.48785
94	12	14.65	0.26109
95	12	9.89	0.62555
96	12	4.45	0.97385
97	12	9.20	0.68599
98	12	5.92	0.92026
99	12	12.26	0.42521
100	12	15.84	0.19862
Combined P-value for all tests (Using KS method)			0.98397

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	13.30	0.34774
2	12	8.03	0.78280
3	12	4.66	0.96827
4	12	10.03	0.61297
5	12	10.02	0.61428
6	12	6.04	0.91415
7	12	7.44	0.82725
8	12	16.70	0.16106
9	12	15.08	0.23711
10	12	8.49	0.74558
11	12	5.63	0.93337
12	12	9.58	0.65273
13	12	10.09	0.60785
14	12	4.23	0.97884
15	12	6.00	0.91587

16	12	7.46	0.82554
17	12	17.09	0.14635
18	12	10.56	0.56678
19	12	14.46	0.27247
20	12	8.00	0.78545
21	12	13.76	0.31614
22	12	7.49	0.82326
23	12	5.65	0.93257
24	12	24.03	0.02014
25	12	9.77	0.63611
26	12	14.56	0.26622
27	12	12.68	0.39256
28	12	26.93	0.00792
29	12	7.51	0.82229
30	12	29.68	0.00312
31	12	12.78	0.38559
32	12	19.79	0.07108
33	12	11.33	0.50065
34	12	7.78	0.80226
35	12	13.98	0.30220
36	12	8.63	0.73396
37	12	12.68	0.39268
38	12	11.36	0.49840
39	12	6.07	0.91262
40	12	15.63	0.20891
41	12	12.13	0.43562
42	12	14.49	0.27059
43	12	17.47	0.13270
44	12	12.17	0.43225
45	12	10.94	0.53365
46	12	14.37	0.27748
47	12	11.98	0.44689
48	12	10.78	0.54818
49	12	10.17	0.60101
50	12	6.68	0.87777
51	12	7.57	0.81808
52	12	13.80	0.31375
53	12	14.24	0.28551
54	12	7.23	0.84221
55	12	14.43	0.27393
56	12	12.69	0.39208
57	12	5.74	0.92850
58	12	8.38	0.75481
59	12	6.51	0.88837
60	12	18.15	0.11121
61	12	10.58	0.56513
62	12	13.91	0.30636
63	12	10.80	0.54580
64	12	3.46	0.99128
65	12	13.61	0.32602
66	12	15.89	0.19649
67	12	12.76	0.38689
68	12	7.41	0.82928
69	12	10.89	0.53853
70	12	10.57	0.56596

71	12	6.34	0.89808
72	12	8.29	0.76203
73	12	11.39	0.49562
74	12	26.21	0.01002
75	12	21.60	0.04223
76	12	7.75	0.80405
77	12	6.72	0.87548
78	12	16.81	0.15680
79	12	20.75	0.05419
80	12	13.82	0.31267
81	12	11.93	0.45096
82	12	19.41	0.07912
83	12	10.63	0.56075
84	12	9.19	0.68632
85	12	7.19	0.84492
86	12	14.21	0.28721
87	12	13.06	0.36467
88	12	13.19	0.35541
89	12	7.01	0.85720
90	12	12.12	0.43581
91	12	5.03	0.95688
92	12	10.36	0.58466
93	12	16.87	0.15465
94	12	14.81	0.25202
95	12	13.27	0.34951
96	12	14.92	0.24598
97	12	9.62	0.64949
98	12	5.47	0.94059
99	12	8.01	0.78465
100	12	12.32	0.42020
Combined P-value for all tests (Using KS method)			0.57506

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)	0.48241	1.00000
Opening Score (Dealer)	0.85119	1.00000
Dealer's Final Score	0.65005	1.00000
Player Cards Rank	0.98397	1.00000
Dealer Cards Rank	0.57506	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.

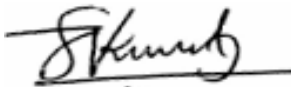
We conclude that the Random Number Generator (RNG) is working correctly.

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.

Signed:



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iTech Labs Australia
Date: 06 October, 2022

Signed:



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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.