



Blackjack Cards Analysis – September 2022

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **September 01, 2022 to September 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	15.70	0.54489
2	17	16.45	0.49246
3	17	17.99	0.38936
4	17	17.76	0.40434
5	17	13.77	0.68353
6	17	17.75	0.40458
7	17	12.72	0.75465
8	17	14.26	0.64836
9	17	10.75	0.86909
10	17	14.37	0.64111
11	17	16.22	0.50809
12	17	14.31	0.64508
13	17	25.10	0.09243
14	17	15.50	0.55981
15	17	14.36	0.64133
16	17	23.18	0.14355
17	17	9.78	0.91276
18	17	7.86	0.96954
19	17	10.36	0.88784
20	17	18.72	0.34488
21	17	20.28	0.26001
22	17	25.02	0.09429
23	17	15.30	0.57404

24	17	19.72	0.28889
25	17	16.18	0.51103
26	17	11.80	0.81198
27	17	19.78	0.28557
28	17	22.20	0.17699
29	17	17.92	0.39363
30	17	7.89	0.96880
31	17	8.93	0.94257
32	17	25.41	0.08587
33	17	17.18	0.44225
34	17	16.05	0.52000
35	17	13.25	0.71950
36	17	14.25	0.64899
37	17	16.38	0.49735
38	17	7.82	0.97021
39	17	19.24	0.31469
40	17	12.53	0.76677
41	17	9.27	0.93150
42	17	19.80	0.28445
43	17	11.52	0.82857
44	17	11.06	0.85318
45	17	17.80	0.40176
46	17	12.01	0.79971
47	17	12.00	0.79997
48	17	21.60	0.20075
49	17	14.74	0.61406
50	17	17.90	0.39509
51	17	11.31	0.83985
52	17	16.00	0.52378
53	17	14.88	0.60408
54	17	7.80	0.97074
55	17	10.07	0.90083
56	17	24.85	0.09821
57	17	21.79	0.19307
58	17	13.76	0.68408
59	17	13.47	0.70442
60	17	16.42	0.49434
61	17	20.83	0.23401
62	17	39.13	0.00171
63	17	17.81	0.40079
64	17	14.78	0.61108
65	17	14.22	0.65177
66	17	12.68	0.75728
67	17	15.33	0.57161
68	17	21.75	0.19443
69	17	10.06	0.90093
70	17	14.37	0.64107
71	17	22.98	0.14975
72	17	23.29	0.14016
73	17	10.81	0.86630
74	17	15.96	0.52693
75	17	11.61	0.82318
76	17	9.44	0.92530
77	17	16.54	0.48571
78	17	12.57	0.76439

79	17	24.97	0.09527
80	17	19.85	0.28179
81	17	16.52	0.48744
82	17	22.59	0.16324
83	17	13.64	0.69247
84	17	16.72	0.47373
85	17	22.65	0.16097
86	17	14.98	0.59688
87	17	22.45	0.16804
88	17	14.95	0.59885
89	17	8.77	0.94707
90	17	12.50	0.76910
91	17	24.22	0.11369
92	17	5.93	0.99365
93	17	23.64	0.12951
94	17	28.75	0.03690
95	17	18.99	0.32908
96	17	27.92	0.04592
97	17	14.30	0.64553
98	17	15.30	0.57377
99	17	10.82	0.86576
100	17	12.61	0.76159
Combined P-value for all tests (Using KS method)			0.20157

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	21.92	0.18796
2	17	17.71	0.40743
3	17	18.49	0.35842
4	17	29.18	0.03292
5	17	10.39	0.88637
6	17	20.31	0.25891
7	17	25.79	0.07835
8	17	35.66	0.00508
9	17	19.00	0.32845
10	17	15.64	0.54955
11	17	4.09	0.99940
12	17	16.22	0.50842
13	17	15.92	0.52926
14	17	12.96	0.73873
15	17	10.02	0.90295
16	17	30.07	0.02583
17	17	15.44	0.56399
18	17	15.34	0.57074
19	17	11.12	0.85029
20	17	13.22	0.72128
21	17	9.76	0.91348
22	17	22.29	0.17368
23	17	13.31	0.71491

24	17	30.79	0.02116
25	17	18.50	0.35792
26	17	13.67	0.69016
27	17	29.83	0.02761
28	17	13.43	0.70706
29	17	19.38	0.30689
30	17	15.17	0.58336
31	17	8.54	0.95352
32	17	10.61	0.87598
33	17	23.25	0.14127
34	17	28.77	0.03668
35	17	14.92	0.60113
36	17	17.73	0.40619
37	17	16.99	0.45489
38	17	13.91	0.67377
39	17	18.15	0.37960
40	17	9.38	0.92757
41	17	22.91	0.15213
42	17	12.35	0.77820
43	17	28.33	0.04118
44	17	11.50	0.82965
45	17	19.03	0.32672
46	17	17.50	0.42076
47	17	26.99	0.05818
48	17	29.82	0.02766
49	17	24.92	0.09661
50	17	16.90	0.46126
51	17	14.31	0.64522
52	17	28.64	0.03799
53	17	26.70	0.06261
54	17	24.25	0.11292
55	17	15.56	0.55518
56	17	35.98	0.00461
57	17	9.34	0.92887
58	17	15.39	0.56773
59	17	10.31	0.88996
60	17	13.94	0.67154
61	17	7.25	0.98007
62	17	24.74	0.10078
63	17	23.16	0.14398
64	17	22.99	0.14972
65	17	14.58	0.62591
66	17	12.56	0.76531
67	17	9.73	0.91446
68	17	14.77	0.61230
69	17	19.67	0.29121
70	17	9.79	0.91208
71	17	20.18	0.26513
72	17	9.55	0.92123
73	17	17.43	0.42593
74	17	11.72	0.81663
75	17	17.16	0.44327
76	17	14.28	0.64702
77	17	16.89	0.46201
78	17	14.12	0.65890

79	17	18.36	0.36617
80	17	15.24	0.57802
81	17	12.77	0.75168
82	17	21.42	0.20812
83	17	9.99	0.90418
84	17	19.60	0.29505
85	17	13.73	0.68586
86	17	14.07	0.66225
87	17	9.04	0.93886
88	17	15.20	0.58084
89	17	6.21	0.99166
90	17	8.78	0.94686
91	17	13.31	0.71534
92	17	16.22	0.50857
93	17	20.66	0.24178
94	17	26.74	0.06203
95	17	21.40	0.20889
96	17	8.01	0.96632
97	17	15.14	0.58517
98	17	18.35	0.36679
99	17	20.78	0.23636
100	17	23.68	0.12853
Combined P-value for all tests (Using KS method)			0.88188

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	65.00	0.07540
2	50	51.98	0.39671
3	50	39.21	0.86429
4	50	49.01	0.51328
5	50	46.43	0.61725
6	50	69.90	0.03294
7	50	82.53	0.00258
8	50	50.23	0.46437
9	50	34.94	0.94767
10	50	24.90	0.99887
11	50	55.29	0.28189
12	50	61.56	0.12661
13	50	50.41	0.45717
14	50	45.22	0.66522
15	50	48.21	0.54544
16	50	48.35	0.53968
17	50	57.39	0.22031
18	50	41.27	0.80571
19	50	47.34	0.58094
20	50	49.34	0.49998
21	50	63.41	0.09645
22	50	47.36	0.57991
23	50	46.78	0.60346

24	50	43.22	0.74011
25	50	46.96	0.59622
26	50	53.50	0.34142
27	50	55.96	0.26120
28	50	53.17	0.35297
29	50	45.95	0.63662
30	50	50.64	0.44818
31	50	56.61	0.24193
32	50	37.30	0.90800
33	50	40.79	0.82025
34	50	51.89	0.40007
35	50	50.59	0.45012
36	50	51.63	0.41006
37	50	42.03	0.78106
38	50	54.05	0.32241
39	50	61.54	0.12695
40	50	44.23	0.70322
41	50	41.76	0.78993
42	50	53.82	0.33042
43	50	54.33	0.31313
44	50	66.22	0.06196
45	50	48.65	0.52785
46	50	76.45	0.00942
47	50	40.07	0.84140
48	50	34.27	0.95617
49	50	52.49	0.37778
50	50	52.15	0.39039
51	50	45.93	0.63742
52	50	40.34	0.83348
53	50	45.63	0.64938
54	50	27.38	0.99618
55	50	59.34	0.17187
56	50	38.43	0.88344
57	50	54.43	0.30951
58	50	40.23	0.83680
59	50	56.70	0.23953
60	50	50.82	0.44123
61	50	53.27	0.34944
62	50	49.62	0.48847
63	50	42.39	0.76919
64	50	46.80	0.60246
65	50	42.58	0.76263
66	50	51.40	0.41871
67	50	49.47	0.49439
68	50	40.72	0.82237
69	50	55.82	0.26520
70	50	47.00	0.59470
71	50	85.73	0.00124
72	50	51.33	0.42137
73	50	52.96	0.36047
74	50	61.18	0.13350
75	50	49.94	0.47589
76	50	56.96	0.23199
77	50	40.50	0.82903
78	50	46.84	0.60086

79	50	56.82	0.23604
80	50	74.65	0.01349
81	50	48.01	0.55374
82	50	64.90	0.07657
83	50	49.30	0.50151
84	50	42.48	0.76619
85	50	55.26	0.28278
86	50	69.96	0.03260
87	50	63.83	0.09037
88	50	49.20	0.50550
89	50	54.60	0.30398
90	50	38.72	0.87653
91	50	50.52	0.45285
92	50	42.51	0.76487
93	50	37.72	0.89933
94	50	63.43	0.09614
95	50	67.32	0.05158
96	50	53.13	0.35451
97	50	73.13	0.01814
98	50	47.81	0.56157
99	50	61.56	0.12650
100	50	55.62	0.27151
Combined P-value for all tests			0.29431

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	14.76	0.25488
2	12	10.48	0.57375
3	12	7.95	0.78903
4	12	9.50	0.66017
5	12	18.63	0.09775
6	12	10.69	0.55609
7	12	9.12	0.69308
8	12	6.62	0.88191
9	12	16.93	0.15214
10	12	23.90	0.02097
11	12	9.47	0.66235
12	12	10.48	0.57384
13	12	14.02	0.29943
14	12	8.45	0.74897
15	12	15.63	0.20902

16	12	11.71	0.46900
17	12	6.12	0.91012
18	12	10.35	0.58572
19	12	3.64	0.98912
20	12	7.42	0.82894
21	12	15.01	0.24078
22	12	16.06	0.18855
23	12	10.46	0.57567
24	12	8.45	0.74905
25	12	8.49	0.74593
26	12	12.30	0.42198
27	12	14.91	0.24634
28	12	8.50	0.74510
29	12	5.79	0.92639
30	12	10.33	0.58721
31	12	5.56	0.93679
32	12	8.18	0.77123
33	12	13.08	0.36325
34	12	9.51	0.65904
35	12	13.21	0.35396
36	12	5.73	0.92931
37	12	7.90	0.79320
38	12	15.15	0.23360
39	12	17.41	0.13492
40	12	7.68	0.80969
41	12	8.59	0.73733
42	12	11.79	0.46269
43	12	14.03	0.29886
44	12	6.25	0.90296
45	12	3.44	0.99156
46	12	10.59	0.56469
47	12	22.43	0.03297
48	12	13.59	0.32765
49	12	11.66	0.47360
50	12	12.64	0.39544
51	12	8.18	0.77091
52	12	16.59	0.16552
53	12	12.02	0.44424
54	12	11.26	0.50669
55	12	10.09	0.60771
56	12	15.70	0.20541
57	12	18.98	0.08906
58	12	16.38	0.17449
59	12	3.47	0.99128
60	12	16.90	0.15324
61	12	14.74	0.25596
62	12	11.63	0.47608
63	12	3.07	0.99501
64	12	15.20	0.23058
65	12	10.54	0.56843
66	12	6.22	0.90480
67	12	9.12	0.69273
68	12	12.52	0.40479
69	12	20.14	0.06456
70	12	5.98	0.91709

71	12	9.56	0.65415
72	12	11.86	0.45691
73	12	9.65	0.64695
74	12	6.92	0.86259
75	12	21.70	0.04097
76	12	7.57	0.81746
77	12	3.09	0.99488
78	12	9.15	0.68977
79	12	19.99	0.06723
80	12	18.64	0.09771
81	12	11.71	0.46939
82	12	12.33	0.41991
83	12	7.27	0.83921
84	12	10.70	0.55513
85	12	17.87	0.11960
86	12	9.00	0.70282
87	12	11.74	0.46679
88	12	9.65	0.64653
89	12	6.40	0.89441
90	12	7.81	0.79972
91	12	13.05	0.36566
92	12	11.12	0.51893
93	12	13.94	0.30429
94	12	10.55	0.56819
95	12	9.72	0.64020
96	12	7.46	0.82567
97	12	6.10	0.91107
98	12	28.60	0.00452
99	12	17.30	0.13869
100	12	15.09	0.23667
Combined P-value for all tests (Using KS method)			0.44662

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	16.82	0.15664
2	12	15.30	0.22557
3	12	10.33	0.58678
4	12	22.97	0.02800
5	12	6.05	0.91379
6	12	12.51	0.40571
7	12	9.36	0.67228
8	12	5.24	0.94957
9	12	14.00	0.30068
10	12	8.57	0.73885
11	12	10.40	0.58090
12	12	12.28	0.42385
13	12	6.47	0.89049
14	12	17.00	0.14966
15	12	15.98	0.19205

16	12	7.42	0.82833
17	12	11.32	0.50145
18	12	18.51	0.10106
19	12	17.29	0.13885
20	12	19.26	0.08252
21	12	10.88	0.53926
22	12	16.28	0.17882
23	12	7.98	0.78647
24	12	20.86	0.05252
25	12	9.27	0.67954
26	12	10.02	0.61457
27	12	8.75	0.72450
28	12	15.18	0.23175
29	12	20.98	0.05072
30	12	9.71	0.64141
31	12	7.44	0.82729
32	12	9.88	0.62613
33	12	8.90	0.71154
34	12	6.35	0.89753
35	12	14.68	0.25928
36	12	19.78	0.07134
37	12	5.47	0.94057
38	12	11.97	0.44834
39	12	7.17	0.84597
40	12	17.36	0.13640
41	12	10.05	0.61139
42	12	20.67	0.05542
43	12	13.39	0.34159
44	12	8.71	0.72731
45	12	23.73	0.02210
46	12	10.82	0.54452
47	12	29.22	0.00365
48	12	6.53	0.88725
49	12	8.98	0.70490
50	12	10.79	0.54658
51	12	9.33	0.67473
52	12	14.28	0.28335
53	12	8.26	0.76426
54	12	18.18	0.11033
55	12	10.36	0.58430
56	12	13.68	0.32184
57	12	9.83	0.63099
58	12	4.03	0.98285
59	12	7.44	0.82696
60	12	15.20	0.23053
61	12	6.03	0.91447
62	12	9.15	0.68984
63	12	7.51	0.82228
64	12	8.68	0.73020
65	12	12.63	0.39648
66	12	6.71	0.87612
67	12	15.27	0.22699
68	12	20.05	0.06610
69	12	10.35	0.58485
70	12	15.60	0.21008

71	12	11.64	0.47511
72	12	15.16	0.23258
73	12	9.10	0.69450
74	12	7.16	0.84707
75	12	7.86	0.79584
76	12	17.07	0.14701
77	12	6.41	0.89427
78	12	13.84	0.31125
79	12	9.54	0.65657
80	12	8.87	0.71369
81	12	16.36	0.17529
82	12	14.71	0.25766
83	12	9.48	0.66184
84	12	23.04	0.02739
85	12	9.83	0.63118
86	12	16.58	0.16606
87	12	13.11	0.36128
88	12	7.35	0.83343
89	12	23.47	0.02397
90	12	7.84	0.79783
91	12	14.39	0.27638
92	12	12.16	0.43296
93	12	15.04	0.23930
94	12	14.42	0.27490
95	12	11.97	0.44772
96	12	4.13	0.98097
97	12	13.32	0.34634
98	12	17.08	0.14644
99	12	9.81	0.63284
100	12	6.11	0.91067
Combined P-value for all tests (Using KS method)			0.84099

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)	0.20157	1.00000
Opening Score (Dealer)	0.88188	1.00000
Dealer's Final Score	0.29431	1.00000
Player Cards Rank	0.44662	1.00000
Dealer Cards Rank	0.84099	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.

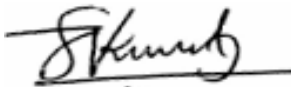
We conclude that the Random Number Generator (RNG) is working correctly.

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: 13 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.