

Blackjack Cards Analysis – October 2023

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **October 01, 2023 to October 31, 2023** 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	17.16	0.44376
2	17	13.24	0.71977
3	17	9.55	0.92130
4	17	18.89	0.33461
5	17	10.19	0.89532
6	17	12.22	0.78637
7	17	13.08	0.73105
8	17	9.90	0.90765
9	17	9.36	0.92829
10	17	24.25	0.11282
11	17	13.07	0.73180
12	17	16.77	0.46999
13	17	17.47	0.42308
14	17	17.13	0.44579
15	17	8.47	0.95543
16	17	23.61	0.13036
17	17	14.06	0.66304
18	17	19.67	0.29139
19	17	23.71	0.12763
20	17	13.14	0.72706
21	17	10.65	0.87411

22	17	18.73	0.34404
23	17	22.12	0.17996
24	17	14.11	0.65910
25	17	11.14	0.84916
26	17	16.44	0.49263
27	17	22.49	0.16667
28	17	18.88	0.33563
29	17	13.45	0.70529
30	17	21.17	0.21864
31	17	16.94	0.45844
32	17	25.61	0.08196
33	17	21.07	0.22333
34	17	20.62	0.24380
35	17	13.18	0.72380
36	17	16.51	0.48817
37	17	5.62	0.99538
38	17	16.10	0.51655
39	17	13.23	0.72066
40	17	25.83	0.07770
41	17	15.80	0.53812
42	17	9.34	0.92891
43	17	29.19	0.03279
44	17	12.70	0.75575
45	17	20.07	0.27087
46	17	12.00	0.79994
47	17	19.19	0.31765
48	17	15.60	0.55220
49	17	22.12	0.18033
50	17	14.08	0.66161
51	17	12.43	0.77322
52	17	24.35	0.11018
53	17	20.29	0.25957
54	17	13.12	0.72820
55	17	8.98	0.94098
56	17	5.79	0.99452
57	17	17.99	0.38923
58	17	18.49	0.35830
59	17	22.02	0.18405
60	17	20.89	0.23123
61	17	15.78	0.53930
62	17	24.10	0.11672
63	17	18.78	0.34144
64	17	19.24	0.31519
65	17	17.66	0.41047
66	17	13.45	0.70544
67	17	11.14	0.84897
68	17	10.59	0.87712
69	17	24.97	0.09533
70	17	8.90	0.94342

71	17	22.22	0.17626
72	17	15.39	0.56770
73	17	16.77	0.47037
74	17	26.43	0.06703
75	17	18.00	0.38882
76	17	21.85	0.19046
77	17	12.49	0.76950
78	17	25.63	0.08151
79	17	12.26	0.78392
80	17	21.66	0.19796
81	17	8.59	0.95225
82	17	9.48	0.92403
83	17	13.27	0.71812
84	17	5.77	0.99459
85	17	9.07	0.93792
86	17	16.62	0.48054
87	17	15.30	0.57419
88	17	8.18	0.96255
89	17	10.01	0.90303
90	17	9.25	0.93209
91	17	31.58	0.01695
92	17	19.70	0.28969
93	17	16.28	0.50392
94	17	19.37	0.30765
95	17	12.38	0.77675
96	17	26.29	0.06929
97	17	8.29	0.95990
98	17	18.12	0.38134
99	17	25.15	0.09139
100	17	17.31	0.43364
Combined P-value for all tests (Using KS method)			0.30898

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	27.32	0.05354
2	17	17.10	0.44732
3	17	11.55	0.82685
4	17	19.55	0.29769
5	17	11.72	0.81663
6	17	17.47	0.42299
7	17	15.87	0.53319
8	17	14.20	0.65254
9	17	10.51	0.88070
10	17	34.69	0.00682
11	17	15.54	0.55633
12	17	26.46	0.06653

13	17	16.15	0.51311
14	17	18.94	0.33221
15	17	20.15	0.26648
16	17	20.98	0.22712
17	17	20.66	0.24173
18	17	27.51	0.05106
19	17	13.27	0.71782
20	17	12.65	0.75951
21	17	19.40	0.30580
22	17	29.29	0.03193
23	17	23.63	0.12992
24	17	13.49	0.70281
25	17	18.70	0.34622
26	17	15.30	0.57389
27	17	8.90	0.94328
28	17	12.61	0.76177
29	17	28.65	0.03787
30	17	14.41	0.63784
31	17	10.84	0.86499
32	17	8.94	0.94198
33	17	17.76	0.40401
34	17	8.19	0.96232
35	17	13.28	0.71712
36	17	28.28	0.04175
37	17	16.04	0.52074
38	17	24.31	0.11132
39	17	11.95	0.80302
40	17	24.04	0.11846
41	17	14.86	0.60530
42	17	25.69	0.08027
43	17	17.27	0.43619
44	17	19.26	0.31368
45	17	17.73	0.40610
46	17	13.15	0.72605
47	17	18.63	0.34996
48	17	7.79	0.97087
49	17	11.06	0.85362
50	17	20.63	0.24344
51	17	20.81	0.23502
52	17	9.82	0.91101
53	17	23.81	0.12456
54	17	14.33	0.64392
55	17	24.34	0.11045
56	17	14.80	0.60978
57	17	24.88	0.09736
58	17	17.13	0.44570
59	17	16.71	0.47451
60	17	17.25	0.43737
61	17	10.84	0.86465

62	17	26.61	0.06402
63	17	14.99	0.59598
64	17	17.32	0.43277
65	17	28.72	0.03720
66	17	9.70	0.91565
67	17	15.70	0.54520
68	17	21.78	0.19337
69	17	20.76	0.23698
70	17	13.54	0.69909
71	17	29.51	0.03013
72	17	18.72	0.34471
73	17	22.56	0.16426
74	17	18.68	0.34732
75	17	26.53	0.06531
76	17	20.19	0.26473
77	17	15.40	0.56667
78	17	11.33	0.83897
79	17	9.94	0.90625
80	17	22.35	0.17164
81	17	17.56	0.41698
82	17	30.03	0.02612
83	17	12.90	0.74311
84	17	13.57	0.69760
85	17	25.76	0.07889
86	17	22.58	0.16344
87	17	18.30	0.37016
88	17	23.28	0.14046
89	17	22.56	0.16402
90	17	14.94	0.59982
91	17	14.40	0.63831
92	17	13.06	0.73220
93	17	15.02	0.59389
94	17	8.47	0.95542
95	17	11.68	0.81936
96	17	12.71	0.75565
97	17	18.60	0.35219
98	17	11.22	0.84497
99	17	11.85	0.80894
100	17	13.34	0.71335
Combined P-value for all tests (Using KS method)			0.72363

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	67.35	0.05130
2	50	41.48	0.79905
3	50	43.08	0.74501

4	50	48.69	0.52605
5	50	56.72	0.23892
6	50	52.91	0.36247
7	50	49.41	0.49691
8	50	35.58	0.93846
9	50	35.67	0.93706
10	50	49.01	0.51328
11	50	40.78	0.82070
12	50	44.08	0.70874
13	50	51.11	0.42986
14	50	48.28	0.54263
15	50	63.41	0.09643
16	50	57.51	0.21700
17	50	72.60	0.02005
18	50	48.18	0.54684
19	50	58.91	0.18179
20	50	46.52	0.61367
21	50	53.97	0.32509
22	50	57.31	0.22228
23	50	50.01	0.47312
24	50	64.32	0.08390
25	50	74.65	0.01349
26	50	36.63	0.92077
27	50	54.21	0.31711
28	50	48.57	0.53082
29	50	40.04	0.84197
30	50	53.11	0.35541
31	50	45.70	0.64637
32	50	57.84	0.20839
33	50	44.24	0.70259
34	50	60.21	0.15276
35	50	43.38	0.73430
36	50	40.68	0.82375
37	50	45.05	0.67191
38	50	45.34	0.66072
39	50	41.02	0.81333
40	50	40.10	0.84049
41	50	40.61	0.82575
42	50	51.82	0.40278
43	50	51.04	0.43271
44	50	41.00	0.81403
45	50	37.87	0.89616
46	50	42.50	0.76532
47	50	55.36	0.27955
48	50	44.46	0.69431
49	50	60.00	0.15717
50	50	44.46	0.69457
51	50	46.52	0.61375
52	50	46.55	0.61266

53	50	47.66	0.56781
54	50	55.04	0.28959
55	50	45.00	0.67397
56	50	43.61	0.72615
57	50	52.11	0.39174
58	50	51.21	0.42586
59	50	35.96	0.93239
60	50	55.84	0.26463
61	50	52.16	0.38986
62	50	46.14	0.62899
63	50	78.61	0.00602
64	50	45.37	0.65955
65	50	55.57	0.27310
66	50	56.53	0.24438
67	50	57.90	0.20666
68	50	48.90	0.51739
69	50	44.95	0.67565
70	50	44.82	0.68090
71	50	41.57	0.79614
72	50	53.77	0.33217
73	50	44.63	0.68804
74	50	39.29	0.86217
75	50	57.15	0.22684
76	50	51.42	0.41803
77	50	34.69	0.95098
78	50	56.78	0.23708
79	50	54.93	0.29334
80	50	45.79	0.64285
81	50	37.10	0.91192
82	50	60.08	0.15551
83	50	38.82	0.87403
84	50	58.10	0.20151
85	50	76.65	0.00903
86	50	57.66	0.21305
87	50	40.47	0.82981
88	50	60.22	0.15251
89	50	50.23	0.46422
90	50	41.54	0.79697
91	50	67.48	0.05022
92	50	36.20	0.92834
93	50	59.43	0.16968
94	50	46.42	0.61773
95	50	45.85	0.64048
96	50	46.48	0.61535
97	50	40.40	0.83196
98	50	56.45	0.24660
99	50	39.70	0.85155
100	50	41.73	0.79104
Combined P-value for all tests			0.34150

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	10.25	0.59442
2	12	4.79	0.96465
3	12	10.95	0.53309
4	12	8.78	0.72123
5	12	9.78	0.63532
6	12	9.63	0.64851
7	12	10.96	0.53209
8	12	3.50	0.99083
9	12	15.56	0.21214
10	12	10.57	0.56572
11	12	8.28	0.76269
12	12	12.93	0.37446
13	12	18.05	0.11415
14	12	19.22	0.08333
15	12	18.68	0.09647
16	12	15.67	0.20658
17	12	11.35	0.49946
18	12	10.68	0.55673
19	12	6.70	0.87648
20	12	7.84	0.79747
21	12	10.65	0.55876
22	12	11.52	0.48525
23	12	10.78	0.54823
24	12	9.82	0.63137
25	12	6.82	0.86937
26	12	16.23	0.18093
27	12	10.13	0.60423
28	12	20.71	0.05480
29	12	17.01	0.14928
30	12	8.13	0.77522
31	12	9.68	0.64410
32	12	6.71	0.87593
33	12	9.14	0.69066
34	12	7.86	0.79560
35	12	7.28	0.83834
36	12	9.73	0.64001

37	12	11.96	0.44872
38	12	19.19	0.08393
39	12	15.47	0.21665
40	12	13.65	0.32379
41	12	8.94	0.70797
42	12	11.52	0.48525
43	12	12.66	0.39447
44	12	12.45	0.41055
45	12	11.05	0.52422
46	12	12.13	0.43514
47	12	21.76	0.04035
48	12	18.47	0.10224
49	12	6.47	0.89030
50	12	14.41	0.27546
51	12	11.55	0.48229
52	12	14.21	0.28780
53	12	15.32	0.22430
54	12	21.90	0.03869
55	12	13.78	0.31487
56	12	9.92	0.62335
57	12	8.84	0.71641
58	12	4.23	0.97893
59	12	20.55	0.05730
60	12	11.47	0.48908
61	12	4.57	0.97078
62	12	12.90	0.37634
63	12	12.46	0.40955
64	12	9.48	0.66184
65	12	12.00	0.44556
66	12	10.67	0.55777
67	12	8.84	0.71667
68	12	8.62	0.73492
69	12	5.37	0.94439
70	12	8.02	0.78386
71	12	8.82	0.71821
72	12	11.07	0.52256
73	12	9.78	0.63552
74	12	12.33	0.41962
75	12	7.71	0.80756
76	12	9.65	0.64640
77	12	17.76	0.12311
78	12	10.94	0.53374
79	12	10.57	0.56622
80	12	13.27	0.35003
81	12	13.94	0.30425
82	12	8.57	0.73902
83	12	16.44	0.17185
84	12	7.73	0.80584
85	12	8.15	0.77323

86	12	14.12	0.29314
87	12	15.31	0.22501
88	12	13.79	0.31426
89	12	11.14	0.51715
90	12	15.06	0.23805
91	12	18.50	0.10126
92	12	7.12	0.84960
93	12	4.71	0.96700
94	12	13.46	0.33625
95	12	12.72	0.38970
96	12	8.21	0.76854
97	12	11.68	0.47152
98	12	9.85	0.62950
99	12	14.33	0.27991
100	12	8.20	0.76958
Combined P-value for all tests (Using KS method)			0.60284

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	26.00	0.01072
2	12	17.29	0.13914
3	12	15.13	0.23443
4	12	7.25	0.84052
5	12	8.63	0.73376
6	12	10.40	0.58066
7	12	16.47	0.17046
8	12	7.84	0.79752
9	12	8.23	0.76675
10	12	10.57	0.56601
11	12	11.68	0.47178
12	12	7.44	0.82726
13	12	13.08	0.36311
14	12	13.95	0.30389
15	12	7.89	0.79399
16	12	13.61	0.32626
17	12	14.09	0.29486
18	12	3.75	0.98750
19	12	6.65	0.87970
20	12	18.73	0.09526
21	12	5.97	0.91775
22	12	23.12	0.02673
23	12	4.59	0.97021
24	12	17.52	0.13114
25	12	16.38	0.17455
26	12	7.43	0.82761
27	12	9.42	0.66662
28	12	4.58	0.97065
29	12	6.80	0.87070
30	12	19.79	0.07112
31	12	7.59	0.81657

32	12	8.10	0.77763
33	12	10.87	0.53983
34	12	4.69	0.96740
35	12	8.35	0.75761
36	12	12.06	0.44101
37	12	13.06	0.36451
38	12	10.23	0.59611
39	12	21.26	0.04672
40	12	11.53	0.48411
41	12	5.40	0.94322
42	12	19.23	0.08322
43	12	8.12	0.77564
44	12	7.40	0.82986
45	12	19.36	0.08026
46	12	10.66	0.55798
47	12	9.93	0.62224
48	12	6.01	0.91559
49	12	11.82	0.45994
50	12	13.20	0.35493
51	12	11.13	0.51784
52	12	7.55	0.81957
53	12	16.28	0.17887
54	12	7.46	0.82613
55	12	11.27	0.50582
56	12	16.94	0.15171
57	12	5.00	0.95814
58	12	11.66	0.47298
59	12	14.19	0.28866
60	12	9.46	0.66346
61	12	6.57	0.88470
62	12	9.35	0.67292
63	12	18.03	0.11477
64	12	13.12	0.36061
65	12	10.60	0.56332
66	12	13.76	0.31616
67	12	8.88	0.71315
68	12	7.79	0.80136
69	12	13.67	0.32226
70	12	11.25	0.50752
71	12	10.52	0.57039
72	12	12.06	0.44055
73	12	9.33	0.67430
74	12	11.72	0.46840
75	12	10.87	0.53980
76	12	10.44	0.57757
77	12	8.13	0.77488
78	12	12.40	0.41424
79	12	12.45	0.41043
80	12	11.66	0.47311
81	12	13.14	0.35913
82	12	16.70	0.16113
83	12	3.19	0.99407
84	12	9.09	0.69536
85	12	6.51	0.88794
86	12	13.59	0.32761
87	12	20.01	0.06683

88	12	8.33	0.75848
89	12	7.07	0.85310
90	12	13.94	0.30474
91	12	12.98	0.37039
92	12	18.61	0.09832
93	12	5.36	0.94495
94	12	12.87	0.37863
95	12	20.62	0.05619
96	12	15.29	0.22589
97	12	12.09	0.43822
98	12	10.83	0.54323
99	12	5.45	0.94130
100	12	12.33	0.41945
Combined P-value for all tests (Using KS method)			0.39521

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)	0.30898	1.00000
Opening Score (Dealer)	0.72363	1.00000
Dealer's Final Score	0.34150	1.00000
Player Cards Rank	0.60284	1.00000
Dealer Cards Rank	0.39521	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:



Divya Bhargava
Project Manager
iTech Labs Australia
Date: 23 November 2023

Signed:



Alvin Rizaldi
Chief Executive Officer
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Date: 23 November 2023

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.