



Blackjack Cards Analysis – July 2023

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **July 01, 2023 to July 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	12.61	0.76197
2	17	8.58	0.95241
3	17	5.16	0.99727
4	17	14.70	0.61736
5	17	9.42	0.92610
6	17	25.79	0.07845
7	17	13.99	0.66813
8	17	14.52	0.63036
9	17	7.06	0.98277
10	17	23.37	0.13768
11	17	19.85	0.28198
12	17	21.10	0.22172
13	17	20.32	0.25800
14	17	16.56	0.48433
15	17	14.89	0.60358
16	17	13.09	0.73032
17	17	12.55	0.76578
18	17	26.12	0.07231
19	17	19.85	0.28194
20	17	15.51	0.55892
21	17	18.37	0.36611

22	17	11.99	0.80094
23	17	28.33	0.04128
24	17	19.62	0.29400
25	17	12.18	0.78902
26	17	4.75	0.99838
27	17	13.76	0.68417
28	17	15.50	0.55920
29	17	12.30	0.78152
30	17	17.27	0.43603
31	17	7.09	0.98230
32	17	25.99	0.07462
33	17	20.85	0.23324
34	17	13.21	0.72211
35	17	11.87	0.80766
36	17	16.22	0.50847
37	17	19.44	0.30381
38	17	9.49	0.92380
39	17	10.84	0.86470
40	17	23.67	0.12862
41	17	19.55	0.29808
42	17	17.98	0.38994
43	17	19.61	0.29470
44	17	11.60	0.82383
45	17	17.81	0.40104
46	17	15.47	0.56155
47	17	16.50	0.48860
48	17	10.34	0.88853
49	17	21.90	0.18868
50	17	24.72	0.10113
51	17	21.72	0.19564
52	17	20.59	0.24539
53	17	18.27	0.37211
54	17	21.19	0.21781
55	17	22.38	0.17059
56	17	6.86	0.98529
57	17	13.67	0.69047
58	17	7.28	0.97960
59	17	18.67	0.34805
60	17	9.81	0.91119
61	17	18.76	0.34233
62	17	9.59	0.91983
63	17	36.70	0.00369
64	17	5.76	0.99468
65	17	13.81	0.68082
66	17	18.87	0.33588
67	17	15.38	0.56795
68	17	11.50	0.82954
69	17	9.84	0.91018
70	17	14.95	0.59884

71	17	23.62	0.13010
72	17	33.03	0.01117
73	17	18.94	0.33209
74	17	23.09	0.14637
75	17	19.90	0.27957
76	17	7.05	0.98294
77	17	12.41	0.77480
78	17	17.15	0.44430
79	17	13.20	0.72275
80	17	13.27	0.71812
81	17	11.63	0.82206
82	17	10.79	0.86743
83	17	17.53	0.41928
84	17	19.91	0.27903
85	17	19.11	0.32218
86	17	9.34	0.92888
87	17	13.62	0.69373
88	17	9.53	0.92206
89	17	9.14	0.93585
90	17	8.55	0.95340
91	17	16.98	0.45591
92	17	16.10	0.51649
93	17	17.90	0.39531
94	17	27.26	0.05434
95	17	22.66	0.16048
96	17	14.78	0.61147
97	17	17.24	0.43789
98	17	22.69	0.15958
99	17	16.38	0.49713
100	17	15.05	0.59210
Combined P-value for all tests (Using KS method)			0.37421

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	8.61	0.95182
2	17	8.75	0.94782
3	17	18.60	0.35215
4	17	22.17	0.17845
5	17	16.21	0.50924
6	17	9.84	0.91004
7	17	15.82	0.53696
8	17	22.83	0.15481
9	17	17.10	0.44755
10	17	15.43	0.56485
11	17	35.67	0.00507
12	17	17.64	0.41217

13	17	20.03	0.27280
14	17	15.52	0.55836
15	17	16.25	0.50621
16	17	11.84	0.80996
17	17	14.12	0.65883
18	17	13.67	0.69008
19	17	21.25	0.21552
20	17	27.14	0.05600
21	17	14.85	0.60634
22	17	9.37	0.92786
23	17	22.71	0.15890
24	17	14.48	0.63297
25	17	12.81	0.74907
26	17	11.07	0.85269
27	17	18.41	0.36353
28	17	16.24	0.50671
29	17	16.73	0.47249
30	17	15.18	0.58236
31	17	20.16	0.26601
32	17	15.21	0.58019
33	17	14.09	0.66095
34	17	18.29	0.37096
35	17	20.89	0.23129
36	17	15.25	0.57762
37	17	19.34	0.30911
38	17	12.18	0.78888
39	17	23.69	0.12805
40	17	12.78	0.75094
41	17	7.32	0.97894
42	17	23.11	0.14586
43	17	10.53	0.87985
44	17	20.53	0.24780
45	17	21.10	0.22177
46	17	23.83	0.12420
47	17	8.17	0.96284
48	17	14.49	0.63220
49	17	9.69	0.91613
50	17	15.69	0.54617
51	17	15.02	0.59380
52	17	20.24	0.26231
53	17	15.29	0.57430
54	17	17.18	0.44240
55	17	13.98	0.66836
56	17	20.96	0.22822
57	17	14.85	0.60655
58	17	15.92	0.52944
59	17	6.90	0.98475
60	17	12.03	0.79843
61	17	25.87	0.07688

62	17	16.61	0.48097
63	17	19.61	0.29452
64	17	9.76	0.91323
65	17	24.62	0.10365
66	17	9.71	0.91531
67	17	18.63	0.35037
68	17	20.98	0.22712
69	17	17.88	0.39674
70	17	14.07	0.66245
71	17	14.41	0.63800
72	17	17.87	0.39700
73	17	13.68	0.68952
74	17	10.76	0.86854
75	17	15.53	0.55720
76	17	30.76	0.02138
77	17	12.66	0.75884
78	17	11.97	0.80198
79	17	13.81	0.68053
80	17	16.58	0.48306
81	17	14.17	0.65536
82	17	16.37	0.49772
83	17	12.45	0.77190
84	17	13.67	0.69028
85	17	19.62	0.29400
86	17	13.74	0.68523
87	17	17.73	0.40607
88	17	17.81	0.40115
89	17	6.96	0.98412
90	17	29.26	0.03217
91	17	19.51	0.30017
92	17	15.73	0.54301
93	17	15.47	0.56158
94	17	12.18	0.78920
95	17	7.27	0.97978
96	17	17.09	0.44799
97	17	19.50	0.30078
98	17	10.33	0.88900
99	17	19.48	0.30143
100	17	17.47	0.42329
Combined P-value for all tests (Using KS method)			0.30621

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	31.31	0.98225
2	50	45.17	0.66702
3	50	44.68	0.68627

4	50	40.84	0.81885
5	50	58.77	0.18512
6	50	32.40	0.97464
7	50	70.43	0.02999
8	50	51.10	0.43015
9	50	38.85	0.87352
10	50	40.36	0.83289
11	50	36.45	0.92415
12	50	58.55	0.19033
13	50	40.15	0.83895
14	50	41.40	0.80143
15	50	42.44	0.76726
16	50	43.19	0.74127
17	50	47.09	0.59084
18	50	75.27	0.01195
19	50	50.47	0.45462
20	50	47.98	0.55486
21	50	49.12	0.50859
22	50	67.67	0.04863
23	50	30.18	0.98807
24	50	56.21	0.25360
25	50	52.69	0.37024
26	50	61.25	0.13224
27	50	53.00	0.35932
28	50	54.07	0.32189
29	50	38.14	0.89019
30	50	49.85	0.47948
31	50	50.98	0.43477
32	50	47.98	0.55499
33	50	60.52	0.14637
34	50	57.63	0.21379
35	50	68.71	0.04068
36	50	35.02	0.94651
37	50	57.57	0.21532
38	50	57.08	0.22884
39	50	48.92	0.51659
40	50	57.53	0.21638
41	50	66.81	0.05616
42	50	33.49	0.96483
43	50	51.41	0.41810
44	50	59.75	0.16258
45	50	46.25	0.62454
46	50	38.23	0.88811
47	50	55.61	0.27175
48	50	53.94	0.32605
49	50	54.80	0.29734
50	50	51.76	0.40505
51	50	58.90	0.18190
52	50	55.77	0.26689

53	50	29.86	0.98939
54	50	61.92	0.12020
55	50	37.98	0.89377
56	50	38.67	0.87773
57	50	33.59	0.96382
58	50	51.66	0.40882
59	50	51.67	0.40821
60	50	53.88	0.32826
61	50	37.40	0.90608
62	50	53.42	0.34444
63	50	68.47	0.04240
64	50	40.53	0.82793
65	50	50.67	0.44679
66	50	57.20	0.22554
67	50	43.88	0.71625
68	50	50.93	0.43698
69	50	33.16	0.96809
70	50	42.74	0.75715
71	50	38.90	0.87215
72	50	61.90	0.12049
73	50	38.58	0.88003
74	50	50.36	0.45899
75	50	37.93	0.89479
76	50	54.55	0.30552
77	50	42.20	0.77556
78	50	61.56	0.12655
79	50	52.27	0.38581
80	50	58.06	0.20266
81	50	56.50	0.24510
82	50	41.40	0.80166
83	50	78.52	0.00614
84	50	47.52	0.57349
85	50	37.36	0.90683
86	50	57.07	0.22901
87	50	58.03	0.20332
88	50	42.51	0.76489
89	50	40.86	0.81824
90	50	60.20	0.15299
91	50	66.26	0.06147
92	50	50.24	0.46381
93	50	28.55	0.99368
94	50	56.46	0.24622
95	50	42.41	0.76830
96	50	44.14	0.70651
97	50	68.48	0.04229
98	50	54.93	0.29320
99	50	55.61	0.27194
100	50	33.47	0.96506
Combined P-value for all tests			0.41682

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	16.45	0.17151
2	12	6.84	0.86785
3	12	9.28	0.67871
4	12	4.41	0.97492
5	12	3.71	0.98805
6	12	16.08	0.18754
7	12	11.70	0.46970
8	12	11.48	0.48812
9	12	16.64	0.16350
10	12	14.03	0.29892
11	12	14.48	0.27097
12	12	21.69	0.04110
13	12	12.27	0.42439
14	12	13.23	0.35224
15	12	16.42	0.17289
16	12	14.14	0.29202
17	12	5.45	0.94143
18	12	23.47	0.02398
19	12	10.50	0.57193
20	12	16.20	0.18244
21	12	8.74	0.72464
22	12	4.44	0.97419
23	12	6.86	0.86680
24	12	10.70	0.55509
25	12	6.63	0.88105
26	12	10.61	0.56287
27	12	10.41	0.57963
28	12	8.98	0.70424
29	12	9.54	0.65658
30	12	9.07	0.69704
31	12	12.63	0.39674
32	12	17.48	0.13247
33	12	8.73	0.72579
34	12	11.70	0.47038
35	12	15.52	0.21404
36	12	16.95	0.15143
37	12	11.25	0.50779

38	12	15.92	0.19484
39	12	15.17	0.23235
40	12	14.04	0.29836
41	12	5.47	0.94036
42	12	8.82	0.71795
43	12	16.82	0.15632
44	12	6.20	0.90589
45	12	11.01	0.52836
46	12	11.96	0.44926
47	12	14.84	0.25033
48	12	14.34	0.27982
49	12	23.17	0.02632
50	12	14.93	0.24549
51	12	10.85	0.54212
52	12	10.55	0.56775
53	12	9.18	0.68710
54	12	15.28	0.22640
55	12	10.84	0.54277
56	12	6.82	0.86946
57	12	9.22	0.68444
58	12	6.72	0.87542
59	12	17.72	0.12448
60	12	14.99	0.24210
61	12	5.10	0.95466
62	12	12.05	0.44173
63	12	15.41	0.21988
64	12	10.73	0.55182
65	12	18.57	0.09933
66	12	5.56	0.93664
67	12	13.14	0.35866
68	12	8.31	0.76073
69	12	10.06	0.61031
70	12	16.38	0.17446
71	12	12.33	0.41989
72	12	13.74	0.31789
73	12	12.99	0.37001
74	12	9.64	0.64750
75	12	14.04	0.29792
76	12	10.31	0.58872
77	12	10.60	0.56382
78	12	25.49	0.01265
79	12	26.89	0.00803
80	12	4.34	0.97658
81	12	10.16	0.60209
82	12	10.66	0.55847
83	12	7.66	0.81079
84	12	13.20	0.35501
85	12	16.07	0.18794
86	12	14.16	0.29073

87	12	10.98	0.53094
88	12	13.85	0.31035
89	12	14.57	0.26588
90	12	9.93	0.62181
91	12	9.85	0.62877
92	12	7.91	0.79233
93	12	7.47	0.82539
94	12	12.28	0.42336
95	12	8.49	0.74543
96	12	18.53	0.10061
97	12	4.24	0.97861
98	12	20.11	0.06505
99	12	3.46	0.99130
100	12	12.83	0.38126
Combined P-value for all tests (Using KS method)			0.92361

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	7.84	0.79746
2	12	8.19	0.77012
3	12	11.97	0.44840
4	12	19.62	0.07455
5	12	9.53	0.65737
6	12	6.53	0.88729
7	12	8.16	0.77287
8	12	8.52	0.74322
9	12	9.56	0.65492
10	12	10.64	0.55961
11	12	6.64	0.88065
12	12	13.59	0.32755
13	12	7.41	0.82963
14	12	25.22	0.01383
15	12	6.37	0.89606
16	12	7.83	0.79815
17	12	5.63	0.93355
18	12	12.60	0.39861
19	12	9.57	0.65375
20	12	7.40	0.82998
21	12	14.98	0.24260
22	12	11.41	0.49441
23	12	19.26	0.08250
24	12	11.79	0.46299
25	12	24.77	0.01596
26	12	5.12	0.95393
27	12	16.15	0.18430
28	12	8.81	0.71945
29	12	14.34	0.27932
30	12	13.36	0.34369
31	12	24.70	0.01631
32	12	7.05	0.85428

33	12	6.22	0.90454
34	12	8.14	0.77421
35	12	10.90	0.53731
36	12	17.50	0.13183
37	12	18.02	0.11515
38	12	14.97	0.24322
39	12	8.50	0.74530
40	12	13.03	0.36706
41	12	13.58	0.32840
42	12	10.43	0.57847
43	12	13.55	0.33026
44	12	9.70	0.64251
45	12	9.69	0.64281
46	12	8.03	0.78248
47	12	8.26	0.76477
48	12	7.72	0.80663
49	12	15.57	0.21192
50	12	5.26	0.94885
51	12	10.22	0.59710
52	12	20.99	0.05048
53	12	6.84	0.86782
54	12	13.82	0.31217
55	12	10.67	0.55748
56	12	9.54	0.65633
57	12	10.10	0.60677
58	12	9.73	0.63925
59	12	5.44	0.94181
60	12	3.94	0.98458
61	12	15.16	0.23280
62	12	5.07	0.95565
63	12	9.01	0.70166
64	12	11.81	0.46081
65	12	6.36	0.89705
66	12	5.09	0.95499
67	12	13.96	0.30306
68	12	5.61	0.93444
69	12	7.76	0.80361
70	12	10.70	0.55510
71	12	9.42	0.66698
72	12	11.73	0.46725
73	12	12.90	0.37608
74	12	7.20	0.84404
75	12	12.01	0.44506
76	12	21.08	0.04924
77	12	13.41	0.34028
78	12	7.40	0.82973
79	12	6.54	0.88646
80	12	6.77	0.87240
81	12	7.91	0.79198
82	12	9.86	0.62832
83	12	11.05	0.52444
84	12	10.32	0.58753
85	12	10.58	0.56531
86	12	11.93	0.45147
87	12	8.21	0.76850
88	12	5.46	0.94093

89	12	13.24	0.35200
90	12	5.82	0.92487
91	12	12.53	0.40440
92	12	10.20	0.59819
93	12	6.86	0.86676
94	12	12.20	0.43015
95	12	7.31	0.83668
96	12	11.90	0.45385
97	12	7.80	0.80053
98	12	18.93	0.09021
99	12	5.31	0.94666
100	12	19.31	0.08139
Combined P-value for all tests (Using KS method)			0.01434

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)	0.37421	1.00000
Opening Score (Dealer)	0.30621	1.00000
Dealer's Final Score	0.41682	1.00000
Player Cards Rank	0.92361	1.00000
Dealer Cards Rank	0.01434	0.07169
Combined P-Value using Holm's Method		0.07169

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.

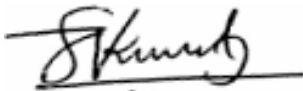
We conclude that the Random Number Generator (RNG) is working correctly.

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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Date: 23 August 2023

Signed:



Alvin Rizaldi
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Date: 23 August 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.