



Blackjack Cards Analysis – September 2023

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **September 01, 2023 to September 30, 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	15.40	0.56659
2	17	25.96	0.07515
3	17	11.06	0.85324
4	17	12.93	0.74090
5	17	19.59	0.29573
6	17	20.41	0.25357
7	17	22.66	0.16060
8	17	21.04	0.22449
9	17	18.62	0.35069
10	17	16.95	0.45790
11	17	17.51	0.42014
12	17	22.79	0.15608
13	17	36.93	0.00344
14	17	13.86	0.67667
15	17	24.31	0.11129
16	17	10.36	0.88779
17	17	24.51	0.10613
18	17	17.87	0.39681
19	17	28.35	0.04106
20	17	20.54	0.24747
21	17	22.31	0.17324
22	17	20.15	0.26647

23	17	14.63	0.62231
24	17	18.57	0.35406
25	17	16.17	0.51201
26	17	36.19	0.00433
27	17	24.40	0.10894
28	17	13.49	0.70313
29	17	14.72	0.61542
30	17	15.16	0.58405
31	17	14.73	0.61526
32	17	13.09	0.72990
33	17	19.63	0.29367
34	17	10.08	0.90011
35	17	12.37	0.77737
36	17	16.92	0.45961
37	17	9.17	0.93463
38	17	17.13	0.44569
39	17	17.45	0.42431
40	17	14.23	0.65091
41	17	21.95	0.18656
42	17	14.23	0.65058
43	17	17.35	0.43104
44	17	20.86	0.23244
45	17	18.92	0.33307
46	17	15.05	0.59194
47	17	16.65	0.47846
48	17	16.12	0.51566
49	17	13.27	0.71825
50	17	23.26	0.14088
51	17	23.92	0.12163
52	17	23.62	0.13000
53	17	11.73	0.81642
54	17	18.18	0.37740
55	17	11.48	0.83035
56	17	15.14	0.58550
57	17	12.19	0.78828
58	17	15.84	0.53552
59	17	24.92	0.09642
60	17	32.23	0.01408
61	17	17.07	0.44937
62	17	21.96	0.18621
63	17	9.37	0.92807
64	17	15.54	0.55663
65	17	20.65	0.24211
66	17	15.35	0.57019
67	17	8.47	0.95542
68	17	14.21	0.65249
69	17	15.82	0.53662
70	17	14.64	0.62153
71	17	16.06	0.51987

72	17	28.44	0.04010
73	17	28.07	0.04413
74	17	18.93	0.33228
75	17	18.95	0.33167
76	17	7.65	0.97346
77	17	11.99	0.80050
78	17	7.59	0.97457
79	17	24.28	0.11211
80	17	12.07	0.79590
81	17	15.57	0.55428
82	17	17.21	0.44036
83	17	7.17	0.98119
84	17	14.39	0.63900
85	17	41.87	0.00070
86	17	14.45	0.63534
87	17	9.59	0.91990
88	17	12.34	0.77928
89	17	23.52	0.13303
90	17	34.17	0.00799
91	17	23.78	0.12563
92	17	24.41	0.10874
93	17	11.42	0.83372
94	17	9.39	0.92735
95	17	25.66	0.08094
96	17	12.37	0.77725
97	17	12.90	0.74303
98	17	15.91	0.53014
99	17	13.08	0.73099
100	17	18.90	0.33453
Combined P-value for all tests (Using KS method)			0.73776

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	13.46	0.70489
2	17	15.31	0.57352
3	17	13.34	0.71306
4	17	9.65	0.91761
5	17	16.19	0.51051
6	17	18.92	0.33326
7	17	16.95	0.45763
8	17	11.50	0.82943
9	17	10.91	0.86104
10	17	18.93	0.33263
11	17	11.86	0.80870
12	17	21.67	0.19774
13	17	24.91	0.09675

14	17	19.31	0.31099
15	17	8.10	0.96427
16	17	17.76	0.40431
17	17	11.91	0.80556
18	17	14.71	0.61629
19	17	10.88	0.86268
20	17	20.44	0.25224
21	17	10.41	0.88544
22	17	15.21	0.58005
23	17	12.12	0.79293
24	17	14.77	0.61236
25	17	11.42	0.83419
26	17	18.29	0.37083
27	17	19.49	0.30124
28	17	19.83	0.28276
29	17	11.48	0.83078
30	17	13.62	0.69351
31	17	19.25	0.31451
32	17	18.16	0.37889
33	17	13.09	0.73046
34	17	20.39	0.25491
35	17	20.36	0.25631
36	17	12.49	0.76971
37	17	14.13	0.65823
38	17	23.97	0.12012
39	17	29.84	0.02754
40	17	22.53	0.16526
41	17	7.08	0.98243
42	17	50.54	0.00003
43	17	13.95	0.67064
44	17	9.78	0.91261
45	17	20.06	0.27129
46	17	14.95	0.59917
47	17	16.73	0.47249
48	17	9.68	0.91667
49	17	20.10	0.26904
50	17	10.40	0.88617
51	17	8.22	0.96159
52	17	17.15	0.44436
53	17	9.28	0.93103
54	17	6.84	0.98558
55	17	23.62	0.13005
56	17	20.04	0.27224
57	17	22.36	0.17122
58	17	6.59	0.98831
59	17	24.41	0.10868
60	17	17.08	0.44897
61	17	11.56	0.82599
62	17	9.51	0.92292

63	17	8.58	0.95256
64	17	13.80	0.68136
65	17	6.34	0.99061
66	17	21.07	0.22321
67	17	28.38	0.04064
68	17	11.76	0.81473
69	17	24.49	0.10674
70	17	22.44	0.16854
71	17	21.74	0.19488
72	17	19.07	0.32426
73	17	26.04	0.07378
74	17	8.68	0.94977
75	17	16.41	0.49490
76	17	6.36	0.99041
77	17	8.81	0.94604
78	17	22.80	0.15589
79	17	15.10	0.58827
80	17	17.20	0.44107
81	17	19.19	0.31797
82	17	18.64	0.34980
83	17	32.68	0.01237
84	17	10.42	0.88513
85	17	9.10	0.93697
86	17	15.32	0.57226
87	17	18.41	0.36312
88	17	13.76	0.68370
89	17	14.44	0.63562
90	17	12.90	0.74277
91	17	10.47	0.88270
92	17	22.31	0.17294
93	17	12.09	0.79441
94	17	7.36	0.97844
95	17	22.15	0.17898
96	17	17.21	0.43999
97	17	9.05	0.93855
98	17	17.77	0.40360
99	17	24.56	0.10507
100	17	16.69	0.47551
Combined P-value for all tests (Using KS method)			0.08990

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	68.20	0.04442
2	50	53.23	0.35089
3	50	46.95	0.59663
4	50	46.23	0.62543

5	50	49.58	0.49005
6	50	41.97	0.78300
7	50	38.77	0.87534
8	50	44.76	0.68318
9	50	50.63	0.44835
10	50	41.86	0.78689
11	50	42.64	0.76059
12	50	54.29	0.31420
13	50	55.21	0.28436
14	50	23.41	0.99951
15	50	67.09	0.05362
16	50	45.01	0.67345
17	50	50.12	0.46850
18	50	70.87	0.02768
19	50	50.87	0.43922
20	50	63.18	0.09988
21	50	51.87	0.40082
22	50	55.74	0.26783
23	50	52.02	0.39519
24	50	44.78	0.68218
25	50	50.31	0.46094
26	50	58.81	0.18423
27	50	68.87	0.03956
28	50	66.84	0.05591
29	50	48.38	0.53863
30	50	60.46	0.14768
31	50	48.06	0.55166
32	50	51.49	0.41508
33	50	37.82	0.89727
34	50	49.68	0.48610
35	50	40.94	0.81570
36	50	60.82	0.14052
37	50	72.59	0.02010
38	50	53.12	0.35495
39	50	68.39	0.04295
40	50	51.78	0.40405
41	50	40.19	0.83775
42	50	46.16	0.62819
43	50	33.48	0.96491
44	50	48.61	0.52935
45	50	42.57	0.76281
46	50	53.96	0.32559
47	50	50.69	0.44604
48	50	31.90	0.97843
49	50	53.87	0.32850
50	50	47.34	0.58075
51	50	57.76	0.21038
52	50	59.83	0.16082
53	50	51.06	0.43189

54	50	48.70	0.52571
55	50	61.38	0.12990
56	50	40.08	0.84095
57	50	55.41	0.27809
58	50	34.25	0.95641
59	50	49.16	0.50695
60	50	74.01	0.01529
61	50	45.44	0.65661
62	50	38.71	0.87675
63	50	45.26	0.66367
64	50	45.01	0.67358
65	50	50.75	0.44392
66	50	60.67	0.14344
67	50	37.91	0.89517
68	50	49.58	0.49023
69	50	42.18	0.77612
70	50	48.99	0.51394
71	50	42.93	0.75045
72	50	21.33	0.99987
73	50	63.07	0.10147
74	50	46.43	0.61728
75	50	56.66	0.24042
76	50	50.69	0.44598
77	50	59.19	0.17528
78	50	49.91	0.47710
79	50	34.97	0.94727
80	50	62.16	0.11612
81	50	40.35	0.83318
82	50	63.33	0.09752
83	50	37.47	0.90465
84	50	46.96	0.59610
85	50	64.53	0.08116
86	50	72.89	0.01899
87	50	68.07	0.04541
88	50	52.53	0.37622
89	50	44.66	0.68674
90	50	67.44	0.05052
91	50	42.78	0.75583
92	50	45.87	0.63972
93	50	48.05	0.55210
94	50	41.78	0.78924
95	50	49.75	0.48349
96	50	59.24	0.17400
97	50	71.72	0.02363
98	50	42.49	0.76561
99	50	45.49	0.65467
100	50	55.84	0.26472
Combined P-value for all tests			0.80605

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	15.42	0.21940
2	12	10.28	0.59176
3	12	8.92	0.70963
4	12	13.34	0.34459
5	12	5.56	0.93651
6	12	10.94	0.53384
7	12	25.57	0.01232
8	12	11.19	0.51231
9	12	15.69	0.20566
10	12	20.13	0.06472
11	12	10.98	0.53040
12	12	16.12	0.18565
13	12	9.11	0.69345
14	12	13.34	0.34454
15	12	10.16	0.60198
16	12	11.92	0.45229
17	12	8.63	0.73417
18	12	11.16	0.51537
19	12	13.38	0.34185
20	12	16.38	0.17453
21	12	14.51	0.26953
22	12	5.62	0.93384
23	12	16.43	0.17235
24	12	9.44	0.66455
25	12	10.01	0.61520
26	12	7.70	0.80791
27	12	15.81	0.19997
28	12	14.93	0.24529
29	12	22.27	0.03457
30	12	7.88	0.79449
31	12	4.65	0.96872
32	12	8.74	0.72507
33	12	6.93	0.86225
34	12	16.89	0.15360
35	12	14.70	0.25822
36	12	9.44	0.66473
37	12	11.77	0.46432
38	12	11.87	0.45591

39	12	9.90	0.62462
40	12	12.41	0.41370
41	12	10.43	0.57841
42	12	14.37	0.27787
43	12	18.74	0.09491
44	12	15.55	0.21286
45	12	19.23	0.08304
46	12	9.55	0.65549
47	12	15.52	0.21422
48	12	11.01	0.52789
49	12	18.28	0.10758
50	12	9.74	0.63905
51	12	23.04	0.02739
52	12	6.80	0.87046
53	12	5.14	0.95311
54	12	12.40	0.41422
55	12	10.43	0.57862
56	12	12.61	0.39824
57	12	15.23	0.22894
58	12	9.58	0.65241
59	12	8.49	0.74603
60	12	20.62	0.05616
61	12	10.56	0.56660
62	12	16.94	0.15175
63	12	17.53	0.13083
64	12	6.58	0.88426
65	12	9.15	0.68981
66	12	13.66	0.32312
67	12	14.20	0.28811
68	12	7.77	0.80271
69	12	13.60	0.32687
70	12	2.58	0.99783
71	12	15.78	0.20157
72	12	13.35	0.34435
73	12	14.91	0.24647
74	12	8.75	0.72402
75	12	10.07	0.60987
76	12	6.47	0.89054
77	12	18.36	0.10518
78	12	15.85	0.19827
79	12	33.76	0.00074
80	12	6.89	0.86469
81	12	11.37	0.49733
82	12	14.60	0.26378
83	12	20.23	0.06281
84	12	15.60	0.21027
85	12	16.55	0.16722
86	12	20.17	0.06389
87	12	9.68	0.64440

88	12	10.25	0.59425
89	12	9.11	0.69378
90	12	23.59	0.02312
91	12	10.49	0.57294
92	12	9.74	0.63917
93	12	13.72	0.31870
94	12	19.99	0.06732
95	12	24.12	0.01961
96	12	10.34	0.58629
97	12	11.25	0.50725
98	12	12.82	0.38190
99	12	9.79	0.63472
100	12	5.96	0.91818
Combined P-value for all tests (Using KS method)			0.19716

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	9.29	0.67811
2	12	10.64	0.55960
3	12	9.13	0.69146
4	12	12.33	0.41984
5	12	6.41	0.89426
6	12	4.66	0.96825
7	12	13.69	0.32108
8	12	6.67	0.87884
9	12	12.32	0.42010
10	12	20.88	0.05211
11	12	12.51	0.40534
12	12	13.50	0.33350
13	12	8.45	0.74869
14	12	11.56	0.48197
15	12	5.46	0.94090
16	12	10.25	0.59388
17	12	6.88	0.86561
18	12	17.67	0.12613
19	12	4.56	0.97122
20	12	5.34	0.94555
21	12	6.90	0.86394
22	12	5.74	0.92880
23	12	21.52	0.04322
24	12	15.53	0.21383
25	12	11.37	0.49717
26	12	8.62	0.73528
27	12	12.08	0.43922
28	12	27.57	0.00640
29	12	11.58	0.48026
30	12	12.54	0.40362
31	12	9.16	0.68881
32	12	12.37	0.41611
33	12	17.58	0.12906

34	12	5.19	0.95133
35	12	9.13	0.69152
36	12	6.37	0.89635
37	12	7.89	0.79335
38	12	9.77	0.63600
39	12	11.03	0.52619
40	12	12.86	0.37894
41	12	7.58	0.81718
42	12	6.33	0.89877
43	12	10.58	0.56561
44	12	11.46	0.48995
45	12	9.94	0.62082
46	12	11.12	0.51860
47	12	8.96	0.70657
48	12	18.91	0.09069
49	12	19.90	0.06896
50	12	9.40	0.66814
51	12	9.04	0.69974
52	12	6.23	0.90397
53	12	9.11	0.69346
54	12	14.68	0.25916
55	12	15.85	0.19820
56	12	17.36	0.13640
57	12	11.46	0.49035
58	12	9.88	0.62664
59	12	14.27	0.28400
60	12	5.19	0.95125
61	12	10.99	0.52953
62	12	8.47	0.74768
63	12	8.04	0.78228
64	12	9.17	0.68792
65	12	5.93	0.91979
66	12	10.69	0.55562
67	12	5.78	0.92671
68	12	6.78	0.87153
69	12	15.84	0.19868
70	12	6.27	0.90210
71	12	7.10	0.85063
72	12	12.56	0.40179
73	12	22.08	0.03666
74	12	12.44	0.41118
75	12	14.21	0.28763
76	12	14.95	0.24435
77	12	11.08	0.52186
78	12	14.73	0.25665
79	12	16.04	0.18924
80	12	10.83	0.54325
81	12	11.35	0.49947
82	12	12.17	0.43199
83	12	21.84	0.03933
84	12	17.35	0.13690
85	12	11.72	0.46835
86	12	11.72	0.46807
87	12	23.22	0.02592
88	12	12.17	0.43231
89	12	11.54	0.48356

90	12	9.58	0.65246
91	12	12.64	0.39566
92	12	7.15	0.84776
93	12	7.52	0.82134
94	12	5.87	0.92265
95	12	4.50	0.97267
96	12	15.70	0.20559
97	12	6.98	0.85898
98	12	9.57	0.65322
99	12	15.36	0.22220
100	12	9.48	0.66126
Combined P-value for all tests (Using KS method)			0.04575

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)	0.73776	1.00000
Opening Score (Dealer)	0.08990	0.35960
Dealer's Final Score	0.80605	1.00000
Player Cards Rank	0.19716	0.59147
Dealer Cards Rank	0.04575	0.22877
Combined P-Value using Holm's Method		0.22877

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: 18 October 2023

Signed:



Alvin Rizaldi
Chief Executive Officer
iTech Labs Australia
Date: 18 October 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.