



Blackjack Cards Analysis – March 2023

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **March 01, 2023 to March 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	22.47	0.16717
2	17	12.53	0.76695
3	17	27.13	0.05614
4	17	11.60	0.82366
5	17	18.82	0.33907
6	17	12.35	0.77875
7	17	13.97	0.66911
8	17	19.23	0.31548
9	17	20.86	0.23280
10	17	13.95	0.67098
11	17	10.38	0.88678
12	17	10.82	0.86574
13	17	14.08	0.66132
14	17	21.60	0.20056
15	17	15.91	0.53050
16	17	15.77	0.53986
17	17	20.73	0.23866
18	17	14.77	0.61187
19	17	11.18	0.84718
20	17	15.52	0.55822
21	17	19.71	0.28924
22	17	9.39	0.92717
23	17	12.20	0.78789
24	17	26.20	0.07096

25	17	22.11	0.18050
26	17	16.83	0.46597
27	17	11.36	0.83711
28	17	25.25	0.08934
29	17	12.12	0.79294
30	17	15.67	0.54739
31	17	20.67	0.24149
32	17	21.38	0.20996
33	17	13.44	0.70633
34	17	7.43	0.97734
35	17	17.28	0.43540
36	17	9.81	0.91129
37	17	12.03	0.79843
38	17	22.37	0.17103
39	17	16.96	0.45720
40	17	6.23	0.99148
41	17	16.69	0.47556
42	17	25.28	0.08853
43	17	21.26	0.21506
44	17	16.63	0.47970
45	17	10.33	0.88920
46	17	14.41	0.63803
47	17	16.58	0.48339
48	17	22.67	0.16022
49	17	12.62	0.76150
50	17	21.53	0.20352
51	17	18.17	0.37836
52	17	14.75	0.61384
53	17	11.94	0.80353
54	17	17.40	0.42739
55	17	15.86	0.53374
56	17	16.53	0.48648
57	17	13.16	0.72531
58	17	16.60	0.48184
59	17	23.08	0.14659
60	17	24.77	0.10006
61	17	17.58	0.41578
62	17	13.90	0.67444
63	17	12.54	0.76656
64	17	17.70	0.40819
65	17	8.42	0.95682
66	17	20.28	0.26011
67	17	5.13	0.99737
68	17	21.81	0.19224
69	17	13.87	0.67618
70	17	28.79	0.03651
71	17	17.13	0.44580
72	17	13.74	0.68538
73	17	23.02	0.14852
74	17	12.45	0.77240
75	17	11.76	0.81443
76	17	18.05	0.38573
77	17	17.15	0.44427
78	17	11.70	0.81811
79	17	27.30	0.05385

80	17	19.16	0.31960
81	17	16.41	0.49492
82	17	16.62	0.48012
83	17	11.46	0.83190
84	17	14.38	0.64021
85	17	18.43	0.36194
86	17	18.61	0.35121
87	17	13.39	0.71005
88	17	14.80	0.60961
89	17	26.44	0.06683
90	17	14.74	0.61398
91	17	20.46	0.25158
92	17	10.37	0.88726
93	17	27.45	0.05179
94	17	18.07	0.38447
95	17	19.58	0.29647
96	17	17.07	0.44946
97	17	25.06	0.09338
98	17	12.80	0.74946
99	17	20.39	0.25484
100	17	23.76	0.12619
Combined P-value for all tests (Using KS method)			0.99162

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	14.62	0.62269
2	17	14.75	0.61317
3	17	17.55	0.41762
4	17	23.72	0.12724
5	17	26.48	0.06611
6	17	18.69	0.34670
7	17	8.65	0.95071
8	17	18.72	0.34485
9	17	17.78	0.40274
10	17	12.84	0.74695
11	17	9.29	0.93080
12	17	10.33	0.88899
13	17	15.75	0.54147
14	17	13.90	0.67439
15	17	16.34	0.50015
16	17	12.00	0.80021
17	17	18.40	0.36416
18	17	12.31	0.78088
19	17	19.01	0.32819
20	17	28.93	0.03518
21	17	15.82	0.53676
22	17	15.83	0.53590
23	17	7.90	0.96863
24	17	10.98	0.85736

25	17	10.95	0.85902
26	17	27.48	0.05145
27	17	16.22	0.50841
28	17	14.73	0.61502
29	17	18.40	0.36390
30	17	5.99	0.99323
31	17	24.25	0.11282
32	17	25.23	0.08959
33	17	12.99	0.73699
34	17	26.03	0.07391
35	17	20.13	0.26767
36	17	19.55	0.29804
37	17	9.38	0.92746
38	17	13.96	0.67000
39	17	15.67	0.54730
40	17	11.03	0.85482
41	17	17.23	0.43892
42	17	23.33	0.13872
43	17	19.29	0.31204
44	17	16.48	0.48993
45	17	12.34	0.77909
46	17	11.26	0.84283
47	17	13.10	0.72925
48	17	25.04	0.09390
49	17	16.99	0.45502
50	17	31.34	0.01815
51	17	9.78	0.91258
52	17	13.31	0.71497
53	17	14.14	0.65715
54	17	19.24	0.31513
55	17	22.70	0.15942
56	17	24.49	0.10663
57	17	18.64	0.34951
58	17	9.04	0.93902
59	17	19.98	0.27549
60	17	16.55	0.48509
61	17	13.85	0.67767
62	17	17.92	0.39405
63	17	15.51	0.55889
64	17	21.66	0.19808
65	17	12.21	0.78717
66	17	15.35	0.57038
67	17	10.80	0.86683
68	17	14.98	0.59674
69	17	12.62	0.76132
70	17	14.31	0.64473
71	17	9.80	0.91169
72	17	11.29	0.84109
73	17	21.56	0.20240
74	17	14.28	0.64708
75	17	9.46	0.92474
76	17	23.34	0.13865
77	17	11.79	0.81262
78	17	7.92	0.96831
79	17	20.17	0.26550

80	17	12.38	0.77652
81	17	15.27	0.57617
82	17	9.82	0.91096
83	17	11.03	0.85520
84	17	21.61	0.19999
85	17	12.85	0.74594
86	17	19.13	0.32092
87	17	29.21	0.03264
88	17	12.98	0.73758
89	17	21.86	0.19023
90	17	15.90	0.53072
91	17	21.90	0.18849
92	17	10.43	0.88460
93	17	9.66	0.91736
94	17	19.13	0.32105
95	17	21.07	0.22330
96	17	13.26	0.71879
97	17	26.23	0.07040
98	17	20.10	0.26933
99	17	29.40	0.03103
100	17	12.52	0.76770
Combined P-value for all tests (Using KS method)			0.61111

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	47.34	0.58092
2	50	61.82	0.12191
3	50	51.79	0.40398
4	50	48.48	0.53453
5	50	48.08	0.55093
6	50	65.23	0.07268
7	50	55.63	0.27110
8	50	44.25	0.70220
9	50	48.39	0.53811
10	50	58.10	0.20152
11	50	63.58	0.09396
12	50	50.68	0.44646
13	50	59.33	0.17189
14	50	54.27	0.31485
15	50	50.94	0.43626
16	50	41.56	0.79663
17	50	51.45	0.41676
18	50	45.53	0.65304
19	50	59.45	0.16939
20	50	65.35	0.07126
21	50	38.84	0.87358
22	50	36.25	0.92756
23	50	50.38	0.45844
24	50	59.57	0.16668

25	50	64.52	0.08126
26	50	46.66	0.60837
27	50	39.90	0.84612
28	50	51.76	0.40484
29	50	45.88	0.63944
30	50	66.80	0.05630
31	50	37.86	0.89634
32	50	58.83	0.18364
33	50	58.72	0.18638
34	50	55.00	0.29113
35	50	48.17	0.54728
36	50	54.15	0.31916
37	50	43.23	0.73984
38	50	65.02	0.07513
39	50	61.11	0.13481
40	50	56.04	0.25876
41	50	42.53	0.76414
42	50	41.64	0.79396
43	50	53.75	0.33291
44	50	51.19	0.42669
45	50	45.34	0.66074
46	50	50.23	0.46433
47	50	49.60	0.48943
48	50	39.59	0.85451
49	50	51.82	0.40276
50	50	38.76	0.87559
51	50	49.51	0.49289
52	50	58.69	0.18707
53	50	48.24	0.54418
54	50	38.59	0.87975
55	50	35.12	0.94511
56	50	52.13	0.39094
57	50	44.98	0.67475
58	50	52.32	0.38389
59	50	36.03	0.93130
60	50	58.65	0.18805
61	50	63.16	0.10005
62	50	46.61	0.61009
63	50	38.78	0.87520
64	50	57.91	0.20638
65	50	51.83	0.40218
66	50	33.81	0.96146
67	50	59.74	0.16275
68	50	62.27	0.11419
69	50	51.44	0.41702
70	50	49.75	0.48319
71	50	31.40	0.98165
72	50	44.40	0.69681
73	50	44.74	0.68388
74	50	53.94	0.32615
75	50	58.29	0.19682
76	50	50.39	0.45801
77	50	62.32	0.11339
78	50	55.82	0.26528
79	50	49.96	0.47482

80	50	36.46	0.92390
81	50	80.52	0.00401
82	50	54.64	0.30268
83	50	46.67	0.60760
84	50	48.24	0.54441
85	50	61.33	0.13069
86	50	54.95	0.29251
87	50	55.19	0.28505
88	50	41.34	0.80359
89	50	55.33	0.28057
90	50	51.74	0.40573
91	50	38.58	0.88002
92	50	48.99	0.51371
93	50	53.05	0.35752
94	50	65.19	0.07313
95	50	56.01	0.25960
96	50	54.53	0.30646
97	50	59.39	0.17063
98	50	40.34	0.83351
99	50	40.48	0.82961
100	50	52.98	0.35999
Combined P-value for all tests			0.10888

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	4.73	0.96632
2	12	6.59	0.88337
3	12	11.62	0.47660
4	12	8.63	0.73389
5	12	9.73	0.63939
6	12	6.97	0.85958
7	12	8.19	0.76987
8	12	9.78	0.63490
9	12	12.49	0.40720
10	12	15.92	0.19508
11	12	13.22	0.35306
12	12	10.19	0.59923
13	12	9.32	0.67537
14	12	15.47	0.21697
15	12	10.18	0.59982
16	12	7.65	0.81220
17	12	7.64	0.81257

18	12	12.12	0.43591
19	12	11.22	0.51032
20	12	16.09	0.18729
21	12	13.05	0.36536
22	12	14.50	0.26972
23	12	7.01	0.85720
24	12	13.77	0.31572
25	12	6.05	0.91345
26	12	12.82	0.38194
27	12	8.53	0.74266
28	12	19.08	0.08659
29	12	8.12	0.77548
30	12	11.09	0.52130
31	12	9.59	0.65171
32	12	4.73	0.96632
33	12	12.05	0.44146
34	12	11.20	0.51224
35	12	10.97	0.53150
36	12	10.19	0.59967
37	12	17.98	0.11638
38	12	26.60	0.00882
39	12	11.24	0.50861
40	12	14.18	0.28943
41	12	15.60	0.21006
42	12	13.88	0.30853
43	12	11.69	0.47120
44	12	4.28	0.97794
45	12	13.34	0.34458
46	12	13.81	0.31302
47	12	13.85	0.31026
48	12	16.29	0.17833
49	12	7.58	0.81737
50	12	9.16	0.68887
51	12	8.17	0.77189
52	12	6.55	0.88591
53	12	5.29	0.94753
54	12	11.46	0.48962
55	12	8.89	0.71257
56	12	9.05	0.69899
57	12	15.29	0.22574
58	12	9.23	0.68292
59	12	10.64	0.56026
60	12	11.45	0.49105
61	12	16.84	0.15570
62	12	8.03	0.78275
63	12	9.73	0.63969
64	12	7.78	0.80188
65	12	9.83	0.63107
66	12	10.92	0.53588
67	12	14.29	0.28233
68	12	8.35	0.75704
69	12	11.99	0.44663
70	12	13.37	0.34300
71	12	7.15	0.84751
72	12	8.19	0.76988

73	12	15.88	0.19664
74	12	18.06	0.11388
75	12	11.94	0.45050
76	12	10.63	0.56111
77	12	13.92	0.30573
78	12	17.88	0.11945
79	12	25.74	0.01168
80	12	19.42	0.07895
81	12	3.16	0.99427
82	12	12.31	0.42144
83	12	7.29	0.83785
84	12	13.77	0.31537
85	12	19.26	0.08233
86	12	11.71	0.46956
87	12	9.73	0.63969
88	12	6.68	0.87781
89	12	16.29	0.17819
90	12	8.27	0.76342
91	12	5.25	0.94919
92	12	8.09	0.77769
93	12	9.98	0.61732
94	12	20.92	0.05152
95	12	14.40	0.27607
96	12	6.79	0.87139
97	12	8.42	0.75187
98	12	17.07	0.14691
99	12	10.65	0.55942
100	12	9.58	0.65304
Combined P-value for all tests (Using KS method)			0.53173

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	12.59	0.39942
2	12	11.17	0.51418
3	12	20.50	0.05823
4	12	12.36	0.41737
5	12	10.05	0.61148
6	12	12.76	0.38709
7	12	7.25	0.84048
8	12	7.43	0.82808
9	12	8.88	0.71325
10	12	9.46	0.66351
11	12	12.10	0.43784
12	12	4.45	0.97378
13	12	15.34	0.22329
14	12	13.02	0.36782
15	12	11.33	0.50103
16	12	7.85	0.79701
17	12	12.77	0.38603
18	12	5.53	0.93782

19	12	13.80	0.31364
20	12	14.52	0.26887
21	12	14.62	0.26315
22	12	5.14	0.95326
23	12	12.46	0.40969
24	12	12.16	0.43287
25	12	7.70	0.80812
26	12	10.10	0.60718
27	12	11.28	0.50522
28	12	17.58	0.12908
29	12	9.33	0.67460
30	12	12.13	0.43530
31	12	13.49	0.33468
32	12	6.17	0.90749
33	12	17.33	0.13744
34	12	9.99	0.61703
35	12	26.43	0.00932
36	12	17.63	0.12726
37	12	9.57	0.65372
38	12	11.67	0.47232
39	12	14.80	0.25234
40	12	8.90	0.71115
41	12	9.57	0.65352
42	12	12.97	0.37100
43	12	10.68	0.55644
44	12	9.11	0.69378
45	12	13.11	0.36116
46	12	11.28	0.50502
47	12	11.07	0.52259
48	12	9.15	0.69002
49	12	13.38	0.34218
50	12	16.43	0.17213
51	12	9.89	0.62604
52	12	15.97	0.19247
53	12	10.02	0.61449
54	12	5.48	0.94015
55	12	8.98	0.70486
56	12	5.11	0.95435
57	12	11.91	0.45297
58	12	11.52	0.48519
59	12	9.14	0.69099
60	12	32.04	0.00137
61	12	16.82	0.15643
62	12	17.39	0.13552
63	12	8.74	0.72517
64	12	7.96	0.78794
65	12	12.13	0.43521
66	12	11.65	0.47447
67	12	5.64	0.93306
68	12	11.39	0.49562
69	12	11.07	0.52284
70	12	29.71	0.00309
71	12	13.82	0.31259
72	12	9.17	0.68849
73	12	9.65	0.64701

74	12	11.16	0.51524
75	12	7.18	0.84566
76	12	15.28	0.22663
77	12	8.08	0.77877
78	12	9.03	0.70001
79	12	11.17	0.51464
80	12	10.57	0.56609
81	12	19.49	0.07730
82	12	19.32	0.08112
83	12	15.41	0.21962
84	12	5.83	0.92426
85	12	16.15	0.18436
86	12	17.48	0.13248
87	12	3.81	0.98660
88	12	18.73	0.09520
89	12	9.05	0.69844
90	12	15.15	0.23314
91	12	5.84	0.92406
92	12	18.80	0.09341
93	12	14.78	0.25392
94	12	11.25	0.50772
95	12	5.94	0.91895
96	12	10.12	0.60557
97	12	6.39	0.89494
98	12	8.11	0.77662
99	12	9.25	0.68182
100	12	7.02	0.85651
Combined P-value for all tests (Using KS method)			0.67610

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)	0.99162	1.00000
Opening Score (Dealer)	0.61111	1.00000
Dealer's Final Score	0.10888	0.54442
Player Cards Rank	0.53173	1.00000
Dealer Cards Rank	0.67610	1.00000
Combined P-Value using Holm's Method		0.54442

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.

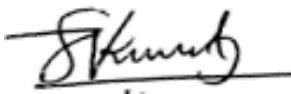
We conclude that the Random Number Generator (RNG) is working correctly.

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:



Kiren Sreekumar
Principal Consultant
iTech Labs Australia
Date: 23 May 2023

Signed:



Alvin Rizaldi
Senior Consultant
iTech Labs Australia
Date: 23 May 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.