



Blackjack Cards Analysis – February 2022

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **February 01, 2022 to February 28, 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	12.25	0.78500
2	17	22.00	0.18462
3	17	8.57	0.95286
4	17	9.23	0.93269
5	17	27.97	0.04527
6	17	11.17	0.84749
7	17	12.90	0.74288
8	17	18.48	0.35932
9	17	13.08	0.73076
10	17	15.74	0.54248
11	17	11.40	0.83517
12	17	16.42	0.49430
13	17	11.48	0.83030
14	17	9.58	0.92028
15	17	14.97	0.59776
16	17	19.17	0.31905
17	17	10.97	0.85824
18	17	20.62	0.24391
19	17	9.92	0.90698
20	17	19.05	0.32593
21	17	11.12	0.85050
22	17	34.02	0.00836
23	17	14.81	0.60927

24	17	18.65	0.34873
25	17	14.26	0.64837
26	17	16.23	0.50793
27	17	7.34	0.97878
28	17	17.65	0.41114
29	17	13.62	0.69345
30	17	11.06	0.85335
31	17	11.60	0.82398
32	17	14.85	0.60626
33	17	21.95	0.18670
34	17	14.34	0.64294
35	17	13.15	0.72599
36	17	16.56	0.48447
37	17	34.45	0.00734
38	17	19.51	0.30002
39	17	18.97	0.33052
40	17	13.93	0.67191
41	17	9.20	0.93373
42	17	14.83	0.60785
43	17	16.44	0.49294
44	17	15.21	0.58006
45	17	15.63	0.55007
46	17	15.10	0.58855
47	17	17.33	0.43219
48	17	22.12	0.18014
49	17	18.15	0.37941
50	17	16.51	0.48830
51	17	20.59	0.24520
52	17	12.96	0.73874
53	17	14.42	0.63709
54	17	15.16	0.58397
55	17	24.29	0.11183
56	17	7.83	0.97002
57	17	11.42	0.83377
58	17	18.55	0.35505
59	17	22.26	0.17492
60	17	18.96	0.33063
61	17	15.52	0.55789
62	17	23.15	0.14444
63	17	13.45	0.70586
64	17	5.51	0.99590
65	17	12.47	0.77116
66	17	9.95	0.90589
67	17	11.17	0.84735
68	17	15.99	0.52473
69	17	18.63	0.35044
70	17	12.78	0.75053
71	17	28.37	0.04075
72	17	16.94	0.45876
73	17	19.93	0.27758
74	17	11.15	0.84849
75	17	10.98	0.85741
76	17	19.57	0.29689
77	17	15.80	0.53773
78	17	7.08	0.98247

79	17	8.15	0.96328
80	17	16.71	0.47427
81	17	18.91	0.33383
82	17	14.18	0.65447
83	17	16.33	0.50032
84	17	10.06	0.90117
85	17	15.79	0.53861
86	17	17.35	0.43074
87	17	23.42	0.13594
88	17	24.74	0.10070
89	17	20.29	0.25966
90	17	10.89	0.86219
91	17	12.31	0.78073
92	17	14.91	0.60184
93	17	11.78	0.81356
94	17	22.90	0.15253
95	17	24.51	0.10627
96	17	17.79	0.40226
97	17	12.88	0.74406
98	17	23.53	0.13292
99	17	16.41	0.49472
100	17	13.28	0.71757
Combined P-value for all tests (Using KS method)			0.13577

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	12.64	0.75981
2	17	9.17	0.93493
3	17	16.98	0.45560
4	17	15.35	0.57042
5	17	15.18	0.58226
6	17	15.18	0.58256
7	17	21.34	0.21150
8	17	11.29	0.84135
9	17	20.16	0.26638
10	17	20.11	0.26857
11	17	23.66	0.12904
12	17	8.53	0.95389
13	17	11.30	0.84031
14	17	20.98	0.22704
15	17	21.77	0.19360
16	17	7.95	0.96766
17	17	11.53	0.82798
18	17	28.78	0.03657
19	17	12.15	0.79086
20	17	18.95	0.33131
21	17	10.22	0.89429
22	17	13.65	0.69189
23	17	23.49	0.13391

24	17	18.71	0.34568
25	17	19.94	0.27744
26	17	11.62	0.82262
27	17	13.97	0.66952
28	17	10.71	0.87146
29	17	19.60	0.29517
30	17	16.66	0.47783
31	17	22.06	0.18252
32	17	23.18	0.14351
33	17	21.42	0.20795
34	17	17.44	0.42518
35	17	16.72	0.47364
36	17	13.55	0.69890
37	17	20.27	0.26083
38	17	9.96	0.90538
39	17	20.03	0.27294
40	17	12.95	0.73922
41	17	27.31	0.05362
42	17	20.29	0.25963
43	17	20.06	0.27142
44	17	20.59	0.24506
45	17	12.69	0.75636
46	17	8.76	0.94751
47	17	13.53	0.70036
48	17	6.59	0.98827
49	17	12.30	0.78142
50	17	23.12	0.14523
51	17	16.34	0.49959
52	17	16.22	0.50853
53	17	4.82	0.99823
54	17	22.13	0.17959
55	17	16.97	0.45630
56	17	23.77	0.12590
57	17	21.78	0.19342
58	17	19.70	0.28960
59	17	18.15	0.37957
60	17	17.71	0.40749
61	17	13.16	0.72545
62	17	15.14	0.58547
63	17	9.17	0.93463
64	17	7.65	0.97346
65	17	16.98	0.45539
66	17	15.09	0.58899
67	17	31.38	0.01797
68	17	26.06	0.07338
69	17	11.35	0.83779
70	17	13.85	0.67796
71	17	22.07	0.18190
72	17	23.23	0.14196
73	17	11.31	0.83979
74	17	10.55	0.87890
75	17	29.74	0.02826
76	17	10.78	0.86787
77	17	11.81	0.81173
78	17	21.02	0.22544

79	17	18.31	0.36943
80	17	14.97	0.59734
81	17	15.38	0.56841
82	17	16.00	0.52386
83	17	14.69	0.61803
84	17	21.54	0.20311
85	17	12.09	0.79443
86	17	20.50	0.24935
87	17	11.58	0.82505
88	17	22.74	0.15774
89	17	17.05	0.45072
90	17	21.18	0.21853
91	17	16.61	0.48125
92	17	9.10	0.93692
93	17	10.01	0.90308
94	17	7.97	0.96720
95	17	21.16	0.21923
96	17	16.35	0.49951
97	17	21.82	0.19161
98	17	20.76	0.23722
99	17	28.17	0.04299
100	17	16.30	0.50238
Combined P-value for all tests (Using KS method)			0.61350

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	54.62	0.30343
2	50	75.06	0.01245
3	50	54.27	0.31516
4	50	57.90	0.20684
5	50	57.20	0.22547
6	50	60.53	0.14634
7	50	48.75	0.52340
8	50	58.15	0.20029
9	50	43.30	0.73712
10	50	52.40	0.38094
11	50	31.54	0.98081
12	50	50.25	0.46334
13	50	52.35	0.38279
14	50	44.18	0.70513
15	50	54.32	0.31329
16	50	58.88	0.18236
17	50	56.65	0.24077
18	50	45.94	0.63711
19	50	58.15	0.20035
20	50	59.30	0.17259
21	50	61.76	0.12304
22	50	42.70	0.75845
23	50	44.25	0.70236

24	50	40.74	0.82198
25	50	68.41	0.04281
26	50	72.46	0.02060
27	50	49.74	0.48364
28	50	31.66	0.98001
29	50	44.87	0.67888
30	50	46.81	0.60216
31	50	47.12	0.58949
32	50	36.38	0.92533
33	50	47.55	0.57243
34	50	59.19	0.17527
35	50	42.61	0.76168
36	50	60.54	0.14596
37	50	39.78	0.84928
38	50	58.25	0.19778
39	50	44.22	0.70346
40	50	47.42	0.57752
41	50	44.73	0.68423
42	50	49.44	0.49597
43	50	61.21	0.13294
44	50	51.83	0.40223
45	50	42.91	0.75130
46	50	49.33	0.50026
47	50	66.33	0.06082
48	50	62.62	0.10851
49	50	32.87	0.97075
50	50	44.68	0.68611
51	50	51.28	0.42331
52	50	62.94	0.10351
53	50	36.60	0.92146
54	50	44.98	0.67466
55	50	38.92	0.87160
56	50	46.33	0.62151
57	50	45.44	0.65668
58	50	57.20	0.22553
59	50	54.30	0.31415
60	50	51.33	0.42138
61	50	69.70	0.03414
62	50	44.13	0.70679
63	50	50.97	0.43544
64	50	55.88	0.26351
65	50	35.74	0.93594
66	50	38.51	0.88165
67	50	44.87	0.67881
68	50	43.49	0.73043
69	50	41.37	0.80237
70	50	55.98	0.26060
71	50	41.64	0.79375
72	50	45.42	0.65753
73	50	51.83	0.40244
74	50	56.95	0.23223
75	50	41.07	0.81195
76	50	40.50	0.82892
77	50	39.65	0.85270
78	50	62.86	0.10469

79	50	67.09	0.05362
80	50	45.58	0.65104
81	50	80.24	0.00426
82	50	39.17	0.86539
83	50	56.92	0.23305
84	50	64.24	0.08486
85	50	63.13	0.10057
86	50	55.77	0.26681
87	50	63.28	0.09828
88	50	41.22	0.80715
89	50	46.44	0.61707
90	50	61.69	0.12418
91	50	46.23	0.62552
92	50	68.27	0.04388
93	50	56.52	0.24444
94	50	60.31	0.15067
95	50	60.47	0.14744
96	50	74.60	0.01363
97	50	39.98	0.84387
98	50	56.36	0.24922
99	50	49.05	0.51158
100	50	52.55	0.37568
Combined P-value for all tests			0.14408

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	9.01	0.70229
2	12	12.35	0.41811
3	12	9.89	0.62576
4	12	8.29	0.76240
5	12	13.03	0.36703
6	12	5.53	0.93776
7	12	17.31	0.13826
8	12	9.61	0.65024
9	12	9.12	0.69226
10	12	16.91	0.15321
11	12	12.89	0.37699
12	12	15.76	0.20259
13	12	11.02	0.52755
14	12	16.81	0.15686
15	12	6.02	0.91503

16	12	11.48	0.48796
17	12	8.62	0.73467
18	12	14.08	0.29558
19	12	11.19	0.51258
20	12	15.39	0.22077
21	12	11.08	0.52199
22	12	18.03	0.11480
23	12	16.67	0.16253
24	12	8.10	0.77695
25	12	5.65	0.93253
26	12	17.16	0.14385
27	12	16.65	0.16331
28	12	9.01	0.70229
29	12	9.57	0.65336
30	12	8.15	0.77308
31	12	9.45	0.66385
32	12	14.55	0.26705
33	12	7.16	0.84676
34	12	15.61	0.20953
35	12	8.09	0.77798
36	12	8.98	0.70451
37	12	11.11	0.51922
38	12	27.94	0.00565
39	12	11.36	0.49803
40	12	7.22	0.84251
41	12	11.41	0.49394
42	12	12.17	0.43240
43	12	9.93	0.62206
44	12	17.67	0.12623
45	12	23.12	0.02671
46	12	17.61	0.12794
47	12	8.38	0.75475
48	12	16.03	0.19006
49	12	16.07	0.18809
50	12	9.89	0.62563
51	12	14.82	0.25120
52	12	8.02	0.78329
53	12	12.35	0.41813
54	12	10.55	0.56746
55	12	14.67	0.26026
56	12	10.48	0.57426
57	12	13.35	0.34408
58	12	18.47	0.10223
59	12	17.54	0.13050
60	12	5.28	0.94778
61	12	5.32	0.94656
62	12	3.62	0.98942
63	12	18.72	0.09556
64	12	9.21	0.68482
65	12	11.12	0.51838
66	12	6.50	0.88875
67	12	26.16	0.01019
68	12	14.26	0.28420
69	12	12.57	0.40078
70	12	13.85	0.31017

71	12	9.33	0.67482
72	12	15.55	0.21291
73	12	11.05	0.52479
74	12	8.89	0.71252
75	12	9.84	0.62994
76	12	13.15	0.35834
77	12	14.18	0.28938
78	12	5.86	0.92285
79	12	11.30	0.50368
80	12	9.58	0.65270
81	12	13.36	0.34327
82	12	8.39	0.75392
83	12	13.67	0.32219
84	12	9.59	0.65219
85	12	14.19	0.28848
86	12	26.06	0.01051
87	12	18.02	0.11502
88	12	7.52	0.82178
89	12	7.22	0.84251
90	12	7.87	0.79517
91	12	8.84	0.71693
92	12	14.21	0.28758
93	12	15.34	0.22361
94	12	8.31	0.76073
95	12	18.22	0.10905
96	12	9.03	0.70071
97	12	16.78	0.15796
98	12	20.60	0.05648
99	12	10.43	0.57829
100	12	7.55	0.81911
Combined P-value for all tests (Using KS method)			0.75094

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	9.31	0.67645
2	12	15.98	0.19193
3	12	16.57	0.16655
4	12	3.22	0.99381
5	12	14.87	0.24880
6	12	25.07	0.01451
7	12	18.03	0.11473
8	12	16.73	0.15997
9	12	13.85	0.31020
10	12	11.69	0.47069
11	12	17.76	0.12328
12	12	6.58	0.88414
13	12	13.05	0.36520
14	12	10.38	0.58234
15	12	14.50	0.26965

16	12	13.04	0.36645
17	12	12.34	0.41876
18	12	15.17	0.23240
19	12	5.70	0.93057
20	12	21.25	0.04690
21	12	14.08	0.29577
22	12	9.56	0.65466
23	12	16.85	0.15537
24	12	17.05	0.14763
25	12	12.43	0.41153
26	12	7.30	0.83683
27	12	9.91	0.62412
28	12	6.95	0.86065
29	12	9.37	0.67070
30	12	10.25	0.59410
31	12	8.20	0.76917
32	12	8.78	0.72193
33	12	5.55	0.93687
34	12	10.28	0.59144
35	12	20.31	0.06138
36	12	5.46	0.94096
37	12	12.55	0.40222
38	12	11.27	0.50576
39	12	11.84	0.45829
40	12	17.24	0.14090
41	12	7.03	0.85550
42	12	7.09	0.85129
43	12	16.01	0.19085
44	12	17.91	0.11843
45	12	13.30	0.34792
46	12	13.89	0.30811
47	12	15.59	0.21074
48	12	7.71	0.80753
49	12	5.74	0.92859
50	12	28.39	0.00485
51	12	7.64	0.81254
52	12	20.61	0.05632
53	12	7.40	0.83039
54	12	19.21	0.08352
55	12	19.97	0.06759
56	12	8.26	0.76412
57	12	8.13	0.77504
58	12	11.63	0.47605
59	12	14.55	0.26696
60	12	22.40	0.03325
61	12	15.42	0.21932
62	12	13.01	0.36850
63	12	5.65	0.93290
64	12	11.15	0.51642
65	12	18.31	0.10649
66	12	11.16	0.51495
67	12	11.87	0.45618
68	12	9.36	0.67220
69	12	14.03	0.29892
70	12	10.55	0.56740

71	12	18.63	0.09780
72	12	10.11	0.60625
73	12	5.63	0.93357
74	12	22.21	0.03529
75	12	7.81	0.79999
76	12	14.62	0.26316
77	12	23.75	0.02201
78	12	17.09	0.14626
79	12	8.98	0.70485
80	12	12.01	0.44464
81	12	15.92	0.19505
82	12	13.56	0.32983
83	12	8.99	0.70374
84	12	14.38	0.27729
85	12	4.90	0.96131
86	12	7.58	0.81671
87	12	12.01	0.44498
88	12	9.65	0.64690
89	12	6.85	0.86724
90	12	9.85	0.62906
91	12	23.27	0.02549
92	12	7.99	0.78578
93	12	8.83	0.71755
94	12	12.24	0.42622
95	12	5.17	0.95196
96	12	6.46	0.89140
97	12	13.16	0.35758
98	12	12.75	0.38733
99	12	8.20	0.76969
100	12	5.03	0.95684
Combined P-value for all tests (Using KS method)			0.92626

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)	0.13577	0.67885
Opening Score (Dealer)	0.61350	1.00000
Dealer's Final Score	0.14408	0.67885
Player Cards Rank	0.75094	1.00000
Dealer Cards Rank	0.92626	1.00000
Combined P-Value using Holm's Method		0.67885

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.

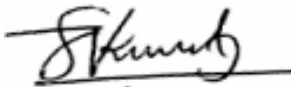
We conclude that the Random Number Generator (RNG) is working correctly.

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: 29 March, 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.