



Blackjack Cards Analysis – May 2022

The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **May 01, 2022 to May 31, 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	17.03	0.45222
2	17	18.53	0.35625
3	17	8.21	0.96187
4	17	11.28	0.84177
5	17	13.03	0.73411
6	17	38.23	0.00229
7	17	24.55	0.10526
8	17	20.81	0.23480
9	17	25.76	0.07901
10	17	16.27	0.50460
11	17	20.65	0.24243
12	17	21.23	0.21621
13	17	26.24	0.07021
14	17	22.42	0.16917
15	17	18.62	0.35090
16	17	20.47	0.25078
17	17	16.67	0.47670
18	17	14.38	0.64029
19	17	13.99	0.66786
20	17	12.20	0.78794
21	17	7.00	0.98350
22	17	10.95	0.85897
23	17	11.00	0.85678

24	17	18.84	0.33783
25	17	12.18	0.78941
26	17	14.69	0.61765
27	17	12.45	0.77214
28	17	19.57	0.29697
29	17	21.83	0.19132
30	17	19.56	0.29726
31	17	16.97	0.45665
32	17	13.13	0.72770
33	17	25.00	0.09463
34	17	20.98	0.22702
35	17	22.14	0.17924
36	17	19.53	0.29885
37	17	17.26	0.43658
38	17	13.68	0.68985
39	17	11.29	0.84101
40	17	21.14	0.21999
41	17	17.27	0.43643
42	17	12.24	0.78565
43	17	22.84	0.15457
44	17	12.95	0.73977
45	17	22.42	0.16911
46	17	16.40	0.49596
47	17	25.72	0.07977
48	17	16.62	0.48034
49	17	22.42	0.16904
50	17	13.21	0.72233
51	17	12.41	0.77448
52	17	19.92	0.27840
53	17	13.98	0.66866
54	17	12.75	0.75299
55	17	13.69	0.68893
56	17	18.97	0.33053
57	17	10.86	0.86399
58	17	25.46	0.08485
59	17	19.41	0.30575
60	17	11.56	0.82579
61	17	19.04	0.32635
62	17	15.18	0.58224
63	17	28.56	0.03885
64	17	25.43	0.08543
65	17	13.27	0.71820
66	17	24.30	0.11139
67	17	29.28	0.03200
68	17	17.43	0.42585
69	17	17.37	0.42932
70	17	25.13	0.09188
71	17	15.44	0.56371
72	17	20.00	0.27445
73	17	10.42	0.88496
74	17	12.96	0.73912
75	17	9.27	0.93152
76	17	8.35	0.95838
77	17	26.77	0.06155
78	17	16.65	0.47846

79	17	13.51	0.70154
80	17	12.82	0.74817
81	17	30.84	0.02089
82	17	24.16	0.11528
83	17	20.60	0.24491
84	17	17.68	0.40941
85	17	15.32	0.57266
86	17	14.91	0.60211
87	17	9.95	0.90565
88	17	31.14	0.01922
89	17	25.46	0.08480
90	17	19.67	0.29131
91	17	9.32	0.92959
92	17	18.97	0.33031
93	17	17.54	0.41834
94	17	10.49	0.88187
95	17	25.03	0.09397
96	17	13.96	0.66984
97	17	6.96	0.98409
98	17	17.63	0.41274
99	17	12.04	0.79796
100	17	13.76	0.68421
Combined P-value for all tests (Using KS method)			0.63190

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	16.84	0.46524
2	17	15.82	0.53679
3	17	10.81	0.86631
4	17	20.92	0.23003
5	17	16.54	0.48621
6	17	12.90	0.74288
7	17	17.96	0.39130
8	17	25.03	0.09400
9	17	13.41	0.70866
10	17	20.09	0.26981
11	17	16.90	0.46122
12	17	23.66	0.12892
13	17	11.10	0.85117
14	17	12.19	0.78879
15	17	17.21	0.44012
16	17	19.92	0.27826
17	17	8.68	0.94967
18	17	18.27	0.37184
19	17	14.46	0.63414
20	17	12.85	0.74638
21	17	13.25	0.71907
22	17	18.15	0.37967
23	17	9.26	0.93183

24	17	14.07	0.66182
25	17	12.71	0.75521
26	17	10.74	0.86994
27	17	14.18	0.65452
28	17	12.82	0.74812
29	17	20.36	0.25637
30	17	24.23	0.11343
31	17	15.09	0.58876
32	17	20.51	0.24921
33	17	18.83	0.33865
34	17	14.24	0.64997
35	17	18.28	0.37120
36	17	16.27	0.50450
37	17	8.23	0.96136
38	17	12.13	0.79211
39	17	12.40	0.77526
40	17	16.52	0.48751
41	17	13.36	0.71148
42	17	17.52	0.41988
43	17	14.57	0.62673
44	17	10.09	0.89991
45	17	27.20	0.05519
46	17	11.84	0.80973
47	17	15.39	0.56710
48	17	16.08	0.51833
49	17	20.82	0.23422
50	17	15.55	0.55565
51	17	8.61	0.95164
52	17	19.59	0.29583
53	17	27.58	0.05014
54	17	21.37	0.21013
55	17	11.48	0.83075
56	17	8.75	0.94775
57	17	14.53	0.62929
58	17	17.75	0.40507
59	17	11.11	0.85074
60	17	19.16	0.31924
61	17	14.98	0.59710
62	17	9.05	0.93884
63	17	18.07	0.38429
64	17	9.27	0.93132
65	17	16.12	0.51542
66	17	19.11	0.32235
67	17	21.15	0.21976
68	17	21.26	0.21502
69	17	12.72	0.75444
70	17	29.14	0.03329
71	17	13.03	0.73387
72	17	26.74	0.06195
73	17	29.47	0.03043
74	17	17.86	0.39799
75	17	14.96	0.59837
76	17	22.46	0.16754
77	17	16.31	0.50181
78	17	28.96	0.03493

79	17	25.70	0.08017
80	17	22.88	0.15333
81	17	19.41	0.30527
82	17	14.17	0.65502
83	17	14.38	0.63978
84	17	16.03	0.52175
85	17	20.85	0.23294
86	17	15.01	0.59447
87	17	16.93	0.45878
88	17	23.30	0.13985
89	17	15.43	0.56418
90	17	12.40	0.77552
91	17	9.99	0.90406
92	17	25.33	0.08766
93	17	16.56	0.48443
94	17	23.00	0.14934
95	17	15.65	0.54909
96	17	7.37	0.97829
97	17	9.93	0.90643
98	17	13.56	0.69831
99	17	12.88	0.74414
100	17	23.43	0.13578
Combined P-value for all tests (Using KS method)			0.83674

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	59.25	0.17381
2	50	45.70	0.64659
3	50	68.45	0.04256
4	50	37.48	0.90445
5	50	51.05	0.43212
6	50	46.97	0.59580
7	50	35.88	0.93370
8	50	48.37	0.53882
9	50	51.36	0.42033
10	50	54.29	0.31438
11	50	47.06	0.59206
12	50	44.76	0.68299
13	50	41.99	0.78259
14	50	60.63	0.14430
15	50	69.46	0.03565
16	50	51.42	0.41809
17	50	52.12	0.39143
18	50	34.20	0.95703
19	50	38.77	0.87525
20	50	47.84	0.56061
21	50	51.51	0.41436
22	50	53.50	0.34140
23	50	43.97	0.71273

24	50	66.71	0.05708
25	50	51.61	0.41060
26	50	32.49	0.97395
27	50	66.42	0.05995
28	50	64.70	0.07901
29	50	48.18	0.54684
30	50	62.34	0.11305
31	50	48.01	0.55359
32	50	35.74	0.93586
33	50	76.92	0.00856
34	50	54.58	0.30477
35	50	62.81	0.10552
36	50	51.81	0.40300
37	50	48.09	0.55035
38	50	46.06	0.63205
39	50	57.62	0.21396
40	50	50.45	0.45548
41	50	46.70	0.60661
42	50	40.38	0.83256
43	50	46.16	0.62823
44	50	55.34	0.28031
45	50	57.09	0.22852
46	50	45.78	0.64310
47	50	55.31	0.28116
48	50	44.51	0.69243
49	50	45.65	0.64839
50	50	79.20	0.00531
51	50	53.35	0.34660
52	50	45.00	0.67376
53	50	47.44	0.57682
54	50	52.41	0.38053
55	50	45.90	0.63858
56	50	39.80	0.84879
57	50	48.84	0.52015
58	50	60.87	0.13950
59	50	38.11	0.89078
60	50	51.34	0.42079
61	50	41.60	0.79535
62	50	48.70	0.52560
63	50	42.00	0.78206
64	50	28.51	0.99378
65	50	40.46	0.83010
66	50	64.12	0.08646
67	50	54.89	0.29459
68	50	55.71	0.26860
69	50	47.23	0.58511
70	50	53.42	0.34444
71	50	57.05	0.22962
72	50	40.66	0.82420
73	50	52.54	0.37591
74	50	57.95	0.20537
75	50	68.01	0.04586
76	50	49.70	0.48547
77	50	53.08	0.35648
78	50	42.61	0.76154

79	50	54.76	0.29867
80	50	44.94	0.67606
81	50	59.64	0.16496
82	50	50.53	0.45260
83	50	52.82	0.36569
84	50	44.61	0.68862
85	50	32.62	0.97287
86	50	50.37	0.45855
87	50	57.33	0.22181
88	50	37.33	0.90751
89	50	60.01	0.15694
90	50	65.03	0.07503
91	50	55.06	0.28911
92	50	53.39	0.34518
93	50	57.53	0.21645
94	50	67.28	0.05197
95	50	62.34	0.11303
96	50	50.31	0.46101
97	50	38.67	0.87787
98	50	38.11	0.89069
99	50	47.08	0.59111
100	50	60.89	0.13910
Combined P-value for all tests			0.41067

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	17.68	0.12570
2	12	17.21	0.14177
3	12	8.51	0.74421
4	12	26.23	0.00994
5	12	12.06	0.44109
6	12	7.52	0.82109
7	12	16.66	0.16277
8	12	10.37	0.58356
9	12	12.84	0.38061
10	12	11.98	0.44695
11	12	23.53	0.02357
12	12	21.10	0.04891
13	12	6.04	0.91430
14	12	15.11	0.23572
15	12	16.89	0.15361

16	12	11.31	0.50292
17	12	8.46	0.74788
18	12	10.11	0.60634
19	12	7.86	0.79635
20	12	10.47	0.57469
21	12	3.78	0.98710
22	12	8.87	0.71439
23	12	5.94	0.91930
24	12	20.42	0.05955
25	12	7.38	0.83120
26	12	9.75	0.63784
27	12	19.36	0.08029
28	12	16.43	0.17237
29	12	10.05	0.61162
30	12	5.56	0.93643
31	12	16.21	0.18179
32	12	4.48	0.97312
33	12	14.90	0.24717
34	12	13.83	0.31177
35	12	15.78	0.20146
36	12	7.20	0.84387
37	12	18.49	0.10163
38	12	7.77	0.80268
39	12	3.21	0.99389
40	12	4.25	0.97851
41	12	23.43	0.02428
42	12	8.59	0.73740
43	12	24.01	0.02028
44	12	11.74	0.46692
45	12	20.05	0.06606
46	12	16.80	0.15737
47	12	14.26	0.28440
48	12	6.42	0.89331
49	12	12.38	0.41566
50	12	4.06	0.98231
51	12	17.45	0.13360
52	12	18.28	0.10749
53	12	12.72	0.38951
54	12	19.27	0.08222
55	12	11.53	0.48420
56	12	12.88	0.37774
57	12	21.05	0.04966
58	12	14.00	0.30069
59	12	15.38	0.22110
60	12	10.34	0.58573
61	12	5.34	0.94584
62	12	10.30	0.59007
63	12	19.00	0.08863
64	12	15.56	0.21245
65	12	11.13	0.51814
66	12	13.60	0.32692
67	12	14.62	0.26290
68	12	24.17	0.01928
69	12	14.01	0.29979
70	12	11.83	0.45929

71	12	16.49	0.16974
72	12	12.92	0.37522
73	12	17.38	0.13588
74	12	14.88	0.24809
75	12	5.55	0.93719
76	12	8.42	0.75134
77	12	10.80	0.54655
78	12	8.23	0.76724
79	12	6.78	0.87184
80	12	5.27	0.94825
81	12	5.73	0.92924
82	12	15.28	0.22629
83	12	11.01	0.52844
84	12	4.39	0.97533
85	12	13.47	0.33585
86	12	8.23	0.76686
87	12	6.35	0.89767
88	12	11.01	0.52814
89	12	21.65	0.04160
90	12	8.28	0.76267
91	12	5.03	0.95712
92	12	7.97	0.78751
93	12	7.81	0.79962
94	12	7.37	0.83254
95	12	11.75	0.46576
96	12	10.70	0.55484
97	12	8.35	0.75750
98	12	19.15	0.08493
99	12	13.32	0.34617
100	12	15.84	0.19848
Combined P-value for all tests (Using KS method)			0.49646

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	32.49	0.00116
2	12	10.77	0.54854
3	12	20.59	0.05664
4	12	13.33	0.34524
5	12	7.04	0.85506
6	12	20.73	0.05449
7	12	15.50	0.21506
8	12	9.25	0.68134
9	12	9.06	0.69761
10	12	7.15	0.84758
11	12	7.26	0.84018
12	12	8.01	0.78441
13	12	8.49	0.74617
14	12	16.37	0.17495
15	12	9.18	0.68748

16	12	8.87	0.71372
17	12	12.37	0.41682
18	12	11.93	0.45125
19	12	16.06	0.18856
20	12	9.09	0.69553
21	12	15.06	0.23796
22	12	5.20	0.95089
23	12	7.03	0.85558
24	12	24.49	0.01744
25	12	10.17	0.60114
26	12	6.86	0.86645
27	12	7.43	0.82817
28	12	13.15	0.35797
29	12	12.48	0.40785
30	12	13.71	0.31966
31	12	17.69	0.12555
32	12	7.35	0.83342
33	12	18.44	0.10303
34	12	9.78	0.63489
35	12	5.64	0.93291
36	12	10.18	0.59985
37	12	9.52	0.65816
38	12	15.00	0.24155
39	12	10.55	0.56810
40	12	14.74	0.25623
41	12	16.41	0.17336
42	12	7.30	0.83691
43	12	6.38	0.89583
44	12	27.95	0.00563
45	12	9.07	0.69687
46	12	5.41	0.94290
47	12	17.74	0.12390
48	12	13.07	0.36418
49	12	25.47	0.01275
50	12	6.04	0.91387
51	12	15.22	0.22986
52	12	15.24	0.22840
53	12	15.62	0.20908
54	12	18.30	0.10693
55	12	15.91	0.19516
56	12	10.62	0.56192
57	12	4.28	0.97786
58	12	24.99	0.01488
59	12	7.45	0.82642
60	12	12.76	0.38649
61	12	6.77	0.87224
62	12	11.03	0.52603
63	12	6.13	0.90914
64	12	13.15	0.35789
65	12	5.36	0.94477
66	12	12.41	0.41334
67	12	13.53	0.33157
68	12	6.03	0.91457
69	12	13.56	0.32964
70	12	10.37	0.58329

71	12	10.77	0.54906
72	12	16.98	0.15038
73	12	20.02	0.06668
74	12	11.11	0.51923
75	12	6.29	0.90063
76	12	20.05	0.06610
77	12	9.63	0.64878
78	12	11.70	0.46996
79	12	13.49	0.33461
80	12	8.09	0.77814
81	12	6.86	0.86692
82	12	11.17	0.51445
83	12	11.49	0.48718
84	12	14.05	0.29728
85	12	16.75	0.15943
86	12	15.75	0.20297
87	12	12.84	0.38113
88	12	13.89	0.30804
89	12	11.79	0.46240
90	12	8.02	0.78348
91	12	10.25	0.59445
92	12	16.91	0.15319
93	12	7.45	0.82669
94	12	11.64	0.47521
95	12	12.78	0.38537
96	12	9.86	0.62843
97	12	19.27	0.08224
98	12	13.68	0.32168
99	12	10.25	0.59364
100	12	10.65	0.55904
Combined P-value for all tests (Using KS method)			0.97984

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)	0.63190	1.00000
Opening Score (Dealer)	0.83674	1.00000
Dealer's Final Score	0.41067	1.00000
Player Cards Rank	0.49646	1.00000
Dealer Cards Rank	0.97984	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.

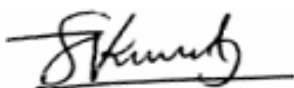
We conclude that the Random Number Generator (RNG) is working correctly.

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:



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iTech Labs Australia
Date: 01 August, 2022

Signed:



Gyulserian Hyussein
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Date: 01 August, 2022

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.