



Blackjack Cards Analysis – October 2020

The Directors

GVC Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **October 01, 2020 to October 31, 2020** 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 GVC 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	18.15	0.37958
2	17	18.94	0.33195
3	17	9.60	0.91950
4	17	17.85	0.39837
5	17	12.93	0.74096
6	17	15.30	0.57382
7	17	25.12	0.09214
8	17	13.67	0.69058
9	17	24.57	0.10474
10	17	16.71	0.47430
11	17	17.97	0.39051
12	17	21.34	0.21142
13	17	23.52	0.13320
14	17	19.61	0.29492
15	17	20.95	0.22836
16	17	10.10	0.89941
17	17	16.38	0.49730
18	17	7.94	0.96782
19	17	19.02	0.32753
20	17	16.60	0.48200
21	17	12.72	0.75489
22	17	14.19	0.65330
23	17	21.32	0.21234
24	17	12.28	0.78273

25	17	24.55	0.10537
26	17	23.95	0.12067
27	17	11.80	0.81189
28	17	21.24	0.21556
29	17	22.20	0.17720
30	17	17.76	0.40435
31	17	18.79	0.34093
32	17	22.30	0.17341
33	17	20.90	0.23069
34	17	10.86	0.86372
35	17	9.32	0.92966
36	17	23.36	0.13803
37	17	43.00	0.00048
38	17	17.17	0.44293
39	17	22.65	0.16089
40	17	22.99	0.14967
41	17	26.78	0.06143
42	17	27.73	0.04819
43	17	16.77	0.47010
44	17	10.45	0.88384
45	17	21.08	0.22289
46	17	19.75	0.28701
47	17	21.75	0.19459
48	17	15.35	0.57013
49	17	14.71	0.61647
50	17	16.61	0.48090
51	17	17.16	0.44343
52	17	13.99	0.66782
53	17	14.56	0.62749
54	17	12.52	0.76747
55	17	20.52	0.24838
56	17	19.68	0.29107
57	17	20.87	0.23215
58	17	15.17	0.58312
59	17	23.16	0.14424
60	17	7.35	0.97853
61	17	10.16	0.89680
62	17	12.63	0.76064
63	17	8.25	0.96086
64	17	18.44	0.36171
65	17	14.85	0.60599
66	17	14.52	0.63016
67	17	9.83	0.91055
68	17	15.00	0.59534
69	17	7.50	0.97610
70	17	14.62	0.62274
71	17	26.14	0.07188
72	17	17.03	0.45219
73	17	17.49	0.42166
74	17	11.38	0.83632
75	17	12.95	0.73921
76	17	20.38	0.25519
77	17	14.24	0.65023
78	17	21.08	0.22287
79	17	28.79	0.03653

80	17	20.95	0.22863
81	17	16.13	0.51494
82	17	13.58	0.69690
83	17	14.16	0.65583
84	17	8.35	0.95857
85	17	12.84	0.74695
86	17	30.40	0.02358
87	17	10.81	0.86634
88	17	4.97	0.99786
89	17	30.43	0.02343
90	17	23.84	0.12385
91	17	15.64	0.54931
92	17	17.13	0.44568
93	17	18.77	0.34184
94	17	14.09	0.66079
95	17	7.17	0.98123
96	17	17.85	0.39812
97	17	27.82	0.04714
98	17	27.14	0.05608
99	17	24.58	0.10446
100	17	21.27	0.21438
Combined P-value for all tests (Using KS method)			0.40669

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	27.78	0.04756
2	17	16.93	0.45904
3	17	10.31	0.89024
4	17	21.71	0.19626
5	17	14.83	0.60767
6	17	11.39	0.83551
7	17	13.94	0.67111
8	17	8.84	0.94502
9	17	15.89	0.53183
10	17	16.91	0.46034
11	17	11.43	0.83331
12	17	26.36	0.06815
13	17	15.63	0.55014
14	17	22.40	0.16981
15	17	9.75	0.91367
16	17	18.48	0.35929
17	17	12.02	0.79921
18	17	14.66	0.62013
19	17	17.77	0.40358
20	17	14.24	0.65030
21	17	13.98	0.66883
22	17	8.16	0.96297
23	17	24.03	0.11869
24	17	19.63	0.29338

25	17	10.98	0.85759
26	17	10.90	0.86197
27	17	20.46	0.25134
28	17	14.84	0.60682
29	17	20.77	0.23678
30	17	14.26	0.64870
31	17	15.90	0.53063
32	17	11.85	0.80911
33	17	14.40	0.63894
34	17	18.63	0.35003
35	17	18.73	0.34399
36	17	15.77	0.53993
37	17	8.75	0.94779
38	17	20.32	0.25810
39	17	30.11	0.02553
40	17	11.84	0.80959
41	17	8.57	0.95270
42	17	24.93	0.09619
43	17	23.99	0.11960
44	17	16.67	0.47680
45	17	18.39	0.36444
46	17	10.42	0.88490
47	17	8.67	0.95008
48	17	21.79	0.19285
49	17	14.95	0.59875
50	17	23.36	0.13785
51	17	14.04	0.66456
52	17	13.23	0.72091
53	17	20.85	0.23289
54	17	15.89	0.53134
55	17	15.14	0.58530
56	17	16.38	0.49679
57	17	12.83	0.74736
58	17	10.77	0.86815
59	17	21.50	0.20481
60	17	13.54	0.69911
61	17	13.51	0.70137
62	17	31.57	0.01699
63	17	16.25	0.50627
64	17	5.95	0.99349
65	17	11.32	0.83953
66	17	10.85	0.86442
67	17	39.35	0.00160
68	17	20.04	0.27202
69	17	13.98	0.66864
70	17	16.55	0.48527
71	17	14.00	0.66727
72	17	31.18	0.01901
73	17	25.10	0.09246
74	17	6.30	0.99097
75	17	10.05	0.90158
76	17	19.46	0.30279
77	17	16.05	0.52034
78	17	20.24	0.26224
79	17	22.07	0.18208

80	17	13.29	0.71630
81	17	31.66	0.01657
82	17	20.47	0.25091
83	17	13.15	0.72587
84	17	13.61	0.69442
85	17	18.42	0.36303
86	17	21.09	0.22242
87	17	22.64	0.16128
88	17	14.10	0.66006
89	17	8.87	0.94410
90	17	17.09	0.44849
91	17	9.05	0.93859
92	17	18.67	0.34769
93	17	9.35	0.92876
94	17	12.92	0.74180
95	17	18.79	0.34066
96	17	10.02	0.90266
97	17	23.44	0.13550
98	17	18.57	0.35349
99	17	21.51	0.20450
100	17	20.95	0.22851
Combined P-value for all tests (Using KS method)			0.86812

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 in hands with 3 or more cards):

Test No.	DOF	ChiSqr	P-Value
1	50	54.06	0.32208
2	50	48.95	0.51559
3	50	59.42	0.16989
4	50	63.51	0.09494
5	50	68.43	0.04265
6	50	38.25	0.88772
7	50	40.39	0.83211
8	50	48.11	0.54963
9	50	76.30	0.00972
10	50	60.87	0.13950
11	50	46.01	0.63438
12	50	56.25	0.25237
13	50	40.48	0.82962
14	50	75.40	0.01164
15	50	63.34	0.09742
16	50	51.34	0.42095
17	50	66.63	0.05792
18	50	59.48	0.16854
19	50	72.98	0.01864
20	50	28.23	0.99446
21	50	52.82	0.36581
22	50	59.14	0.17637
23	50	42.98	0.74878
24	50	38.47	0.88256

25	50	43.65	0.72464
26	50	52.04	0.39459
27	50	54.48	0.30804
28	50	57.40	0.21994
29	50	58.09	0.20197
30	50	61.62	0.12553
31	50	76.08	0.01015
32	50	66.14	0.06274
33	50	70.81	0.02795
34	50	51.59	0.41145
35	50	59.34	0.17184
36	50	50.69	0.44635
37	50	39.09	0.86751
38	50	49.12	0.50862
39	50	38.57	0.88027
40	50	43.41	0.73326
41	50	60.94	0.13806
42	50	44.85	0.67967
43	50	50.17	0.46676
44	50	53.17	0.35323
45	50	61.00	0.13695
46	50	46.75	0.60453
47	50	49.68	0.48607
48	50	53.29	0.34868
49	50	36.57	0.92201
50	50	63.59	0.09376
51	50	59.00	0.17967
52	50	38.44	0.88318
53	50	47.43	0.57707
54	50	39.84	0.84761
55	50	42.00	0.78216
56	50	56.24	0.25277
57	50	45.90	0.63874
58	50	61.84	0.12164
59	50	65.41	0.07056
60	50	42.93	0.75027
61	50	63.62	0.09339
62	50	65.08	0.07444
63	50	51.69	0.40757
64	50	45.44	0.65683
65	50	38.11	0.89073
66	50	43.63	0.72533
67	50	38.59	0.87977
68	50	57.97	0.20488
69	50	58.93	0.18120
70	50	57.65	0.21327
71	50	42.24	0.77419
72	50	49.10	0.50961
73	50	53.05	0.35728
74	50	53.83	0.32995
75	50	50.00	0.47348
76	50	44.49	0.69320
77	50	49.98	0.47429
78	50	56.33	0.25009
79	50	43.50	0.72994

80	50	39.50	0.85680
81	50	67.00	0.05442
82	50	66.02	0.06393
83	50	54.60	0.30419
84	50	53.27	0.34964
85	50	46.10	0.63080
86	50	41.27	0.80550
87	50	45.76	0.64394
88	50	38.47	0.88252
89	50	42.34	0.77085
90	50	57.27	0.22361
91	50	56.41	0.24790
92	50	70.30	0.03068
93	50	51.13	0.42910
94	50	54.60	0.30390
95	50	68.85	0.03971
96	50	50.18	0.46628
97	50	53.12	0.35496
98	50	43.03	0.74676
99	50	55.29	0.28174
100	50	42.50	0.76541
Combined P-value for all tests			0.08433

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	5.70	0.93040
2	12	9.55	0.65572
3	12	10.44	0.57703
4	12	5.14	0.95312
5	12	16.53	0.16821
6	12	5.99	0.91674
7	12	18.44	0.10310
8	12	6.05	0.91352
9	12	20.34	0.06089
10	12	15.69	0.20568
11	12	16.75	0.15933
12	12	18.98	0.08892
13	12	7.06	0.85391
14	12	9.50	0.66001
15	12	9.46	0.66328
16	12	8.60	0.73703

17	12	12.15	0.43403
18	12	21.19	0.04765
19	12	9.53	0.65723
20	12	12.38	0.41589
21	12	7.81	0.79954
22	12	7.58	0.81727
23	12	16.12	0.18590
24	12	6.64	0.88025
25	12	12.34	0.41857
26	12	18.86	0.09201
27	12	8.82	0.71804
28	12	3.23	0.99367
29	12	21.27	0.04662
30	12	8.81	0.71935
31	12	7.86	0.79596
32	12	17.97	0.11671
33	12	11.93	0.45138
34	12	14.95	0.24416
35	12	11.78	0.46342
36	12	7.42	0.82860
37	12	19.00	0.08850
38	12	10.26	0.59316
39	12	10.25	0.59362
40	12	7.18	0.84574
41	12	8.14	0.77422
42	12	25.96	0.01087
43	12	14.37	0.27767
44	12	13.06	0.36449
45	12	9.34	0.67368
46	12	7.80	0.80053
47	12	14.34	0.27972
48	12	5.66	0.93210
49	12	9.49	0.66057
50	12	16.72	0.16029
51	12	8.02	0.78386
52	12	6.11	0.91069
53	12	10.56	0.56704
54	12	7.70	0.80780
55	12	13.47	0.33611
56	12	20.53	0.05770
57	12	6.57	0.88495
58	12	11.70	0.47024
59	12	10.74	0.55169
60	12	12.05	0.44135
61	12	7.73	0.80584
62	12	9.40	0.66826
63	12	10.75	0.55079
64	12	13.87	0.30933
65	12	16.60	0.16511
66	12	14.27	0.28369
67	12	11.37	0.49771
68	12	11.69	0.47089
69	12	8.33	0.75877
70	12	9.32	0.67549
71	12	8.93	0.70900

72	12	9.25	0.68134
73	12	6.11	0.91069
74	12	8.20	0.76966
75	12	18.86	0.09207
76	12	21.82	0.03956
77	12	18.24	0.10869
78	12	7.52	0.82146
79	12	3.66	0.98877
80	12	10.76	0.54921
81	12	10.71	0.55371
82	12	10.18	0.59977
83	12	14.93	0.24545
84	12	17.78	0.12240
85	12	12.08	0.43928
86	12	10.32	0.58815
87	12	25.12	0.01425
88	12	7.76	0.80388
89	12	9.26	0.68021
90	12	22.03	0.03718
91	12	7.96	0.78812
92	12	10.85	0.54225
93	12	16.14	0.18485
94	12	11.13	0.51751
95	12	17.92	0.11823
96	12	34.46	0.00057
97	12	13.11	0.36113
98	12	21.68	0.04124
99	12	7.30	0.83745
100	12	17.04	0.14827
Combined P-value for all tests (Using KS method)			0.59841

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	8.91	0.71043
2	12	6.59	0.88360
3	12	5.34	0.94573
4	12	10.45	0.57620
5	12	8.45	0.74905
6	12	4.78	0.96505
7	12	9.20	0.68576
8	12	18.16	0.11092
9	12	12.97	0.37122
10	12	5.83	0.92431
11	12	13.52	0.33240
12	12	16.04	0.18959
13	12	14.26	0.28441
14	12	10.82	0.54458
15	12	8.91	0.71060
16	12	9.76	0.63683

17	12	13.70	0.32001
18	12	12.96	0.37166
19	12	15.83	0.19905
20	12	17.40	0.13509
21	12	18.48	0.10177
22	12	6.96	0.86051
23	12	15.77	0.20209
24	12	9.42	0.66687
25	12	4.14	0.98074
26	12	14.38	0.27734
27	12	19.11	0.08600
28	12	10.91	0.53630
29	12	8.57	0.73882
30	12	5.97	0.91769
31	12	19.54	0.07627
32	12	9.13	0.69190
33	12	7.94	0.79008
34	12	10.39	0.58149
35	12	3.35	0.99252
36	12	12.10	0.43752
37	12	9.79	0.63455
38	12	12.55	0.40289
39	12	18.72	0.09554
40	12	11.14	0.51664
41	12	10.11	0.60637
42	12	16.05	0.18894
43	12	14.96	0.24373
44	12	10.26	0.59286
45	12	23.26	0.02561
46	12	4.01	0.98325
47	12	13.99	0.30118
48	12	7.89	0.79338
49	12	9.04	0.69971
50	12	9.58	0.65243
51	12	14.98	0.24281
52	12	11.58	0.47965
53	12	22.14	0.03594
54	12	12.43	0.41188
55	12	6.98	0.85918
56	12	12.26	0.42519
57	12	13.66	0.32294
58	12	6.76	0.87335
59	12	8.41	0.75263
60	12	10.61	0.56238
61	12	15.50	0.21548
62	12	8.50	0.74486
63	12	16.07	0.18785
64	12	8.26	0.76468
65	12	8.71	0.72741
66	12	18.73	0.09520
67	12	19.64	0.07428
68	12	11.43	0.49234
69	12	13.13	0.35973
70	12	13.52	0.33247
71	12	10.16	0.60165

72	12	8.14	0.77433
73	12	13.45	0.33743
74	12	4.27	0.97809
75	12	14.35	0.27908
76	12	17.03	0.14830
77	12	20.71	0.05485
78	12	14.45	0.27304
79	12	12.46	0.40930
80	12	12.34	0.41909
81	12	17.22	0.14136
82	12	15.58	0.21140
83	12	15.30	0.22525
84	12	7.30	0.83747
85	12	13.23	0.35220
86	12	20.45	0.05910
87	12	13.89	0.30776
88	12	10.37	0.58360
89	12	9.72	0.64073
90	12	7.38	0.83117
91	12	10.40	0.58100
92	12	8.76	0.72320
93	12	10.52	0.57079
94	12	8.92	0.70985
95	12	12.30	0.42228
96	12	10.89	0.53827
97	12	10.22	0.59660
98	12	11.58	0.47965
99	12	14.77	0.25432
100	12	7.24	0.84141
Combined P-value for all tests (Using KS method)			0.97286

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)	0.40669	1.00000
Opening Score (Dealer)	0.86812	1.00000
Dealer's Final Score	0.08433	0.42166
Player Cards Rank	0.59841	1.00000
Dealer Cards Rank	0.97286	1.00000
Combined P-Value using Holm's Method		0.42166

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.

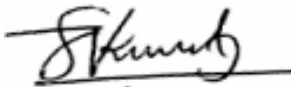
We conclude that the Random Number Generator (RNG) is working correctly.

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: 04 May, 2021

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.