



Blackjack Cards Analysis – November 2020

The Directors

GVC Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **November 01, 2020 to November 30, 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	17.26	0.43695
2	17	16.10	0.51654
3	17	14.52	0.63028
4	17	16.70	0.47465
5	17	9.31	0.92995
6	17	17.48	0.42206
7	17	10.05	0.90149
8	17	13.94	0.67160
9	17	21.47	0.20587
10	17	16.12	0.51562
11	17	19.79	0.28486
12	17	20.55	0.24696
13	17	10.29	0.89098
14	17	15.62	0.55115
15	17	10.79	0.86717
16	17	11.39	0.83575
17	17	16.72	0.47343
18	17	21.07	0.22303
19	17	17.86	0.39747
20	17	23.66	0.12895
21	17	7.89	0.96884
22	17	6.96	0.98405
23	17	12.48	0.77010
24	17	23.50	0.13369

25	17	10.95	0.85903
26	17	16.05	0.52044
27	17	9.23	0.93289
28	17	17.53	0.41917
29	17	13.38	0.71073
30	17	12.73	0.75389
31	17	13.14	0.72699
32	17	13.67	0.69031
33	17	17.85	0.39806
34	17	22.34	0.17196
35	17	16.76	0.47104
36	17	24.19	0.11428
37	17	8.27	0.96045
38	17	23.56	0.13197
39	17	26.58	0.06460
40	17	16.46	0.49126
41	17	14.31	0.64475
42	17	20.15	0.26661
43	17	15.31	0.57309
44	17	16.74	0.47180
45	17	9.31	0.93007
46	17	20.14	0.26698
47	17	36.58	0.00383
48	17	30.40	0.02363
49	17	15.21	0.58065
50	17	20.27	0.26071
51	17	13.74	0.68570
52	17	18.06	0.38513
53	17	35.45	0.00543
54	17	18.19	0.37690
55	17	30.95	0.02027
56	17	15.34	0.57133
57	17	11.79	0.81243
58	17	19.22	0.31620
59	17	12.78	0.75089
60	17	21.15	0.21962
61	17	18.53	0.35646
62	17	14.11	0.65938
63	17	13.26	0.71843
64	17	19.15	0.31981
65	17	11.84	0.80990
66	17	14.51	0.63046
67	17	14.28	0.64708
68	17	8.79	0.94651
69	17	20.41	0.25396
70	17	30.10	0.02562
71	17	26.27	0.06960
72	17	16.26	0.50564
73	17	10.59	0.87697
74	17	15.25	0.57778
75	17	27.43	0.05210
76	17	20.91	0.23053
77	17	15.23	0.57920
78	17	16.25	0.50611
79	17	22.25	0.17514

80	17	18.25	0.37309
81	17	22.78	0.15657
82	17	16.40	0.49567
83	17	14.15	0.65629
84	17	15.35	0.57040
85	17	23.64	0.12946
86	17	16.02	0.52245
87	17	9.60	0.91969
88	17	14.70	0.61725
89	17	23.68	0.12849
90	17	22.51	0.16599
91	17	16.71	0.47450
92	17	17.23	0.43903
93	17	21.94	0.18718
94	17	13.76	0.68377
95	17	10.19	0.89524
96	17	27.17	0.05566
97	17	17.65	0.41092
98	17	26.77	0.06159
99	17	11.62	0.82244
100	17	10.38	0.88684
Combined P-value for all tests (Using KS method)			0.96171

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	16.38	0.49739
2	17	19.78	0.28588
3	17	8.07	0.96507
4	17	9.56	0.92112
5	17	22.53	0.16533
6	17	10.88	0.86268
7	17	21.49	0.20529
8	17	17.96	0.39161
9	17	9.74	0.91418
10	17	18.19	0.37699
11	17	15.07	0.59078
12	17	16.26	0.50562
13	17	14.61	0.62365
14	17	12.68	0.75726
15	17	14.89	0.60310
16	17	11.47	0.83095
17	17	16.82	0.46693
18	17	16.11	0.51585
19	17	15.65	0.54872
20	17	19.28	0.31293
21	17	9.26	0.93182
22	17	17.78	0.40270
23	17	11.40	0.83490
24	17	17.30	0.43411

25	17	26.05	0.07362
26	17	15.69	0.54592
27	17	23.00	0.14925
28	17	11.95	0.80328
29	17	17.10	0.44784
30	17	12.60	0.76256
31	17	10.99	0.85713
32	17	18.04	0.38601
33	17	17.94	0.39239
34	17	16.18	0.51141
35	17	15.73	0.54296
36	17	17.10	0.44739
37	17	27.91	0.04595
38	17	27.79	0.04746
39	17	16.90	0.46115
40	17	12.82	0.74825
41	17	11.41	0.83464
42	17	12.07	0.79608
43	17	24.86	0.09793
44	17	13.62	0.69414
45	17	29.86	0.02737
46	17	14.40	0.63880
47	17	10.02	0.90272
48	17	19.94	0.27719
49	17	12.69	0.75650
50	17	22.47	0.16737
51	17	13.01	0.73548
52	17	14.43	0.63612
53	17	15.91	0.53018
54	17	14.86	0.60544
55	17	8.83	0.94536
56	17	5.87	0.99403
57	17	12.80	0.74975
58	17	12.71	0.75511
59	17	26.22	0.07046
60	17	16.20	0.50938
61	17	10.43	0.88465
62	17	22.19	0.17742
63	17	10.35	0.88831
64	17	26.59	0.06441
65	17	20.42	0.25351
66	17	27.98	0.04522
67	17	30.68	0.02182
68	17	10.87	0.86319
69	17	19.81	0.28393
70	17	15.48	0.56073
71	17	22.81	0.15558
72	17	11.36	0.83719
73	17	16.93	0.45921
74	17	13.76	0.68385
75	17	18.92	0.33301
76	17	18.25	0.37295
77	17	10.03	0.90217
78	17	18.30	0.37016
79	17	15.68	0.54628

80	17	8.35	0.95847
81	17	19.58	0.29617
82	17	13.60	0.69544
83	17	9.89	0.90810
84	17	13.24	0.71993
85	17	16.27	0.50457
86	17	18.78	0.34131
87	17	14.67	0.61892
88	17	14.83	0.60744
89	17	16.64	0.47873
90	17	13.00	0.73624
91	17	9.69	0.91597
92	17	14.63	0.62180
93	17	27.67	0.04898
94	17	19.18	0.31837
95	17	20.08	0.27038
96	17	15.76	0.54090
97	17	13.82	0.68011
98	17	8.69	0.94940
99	17	17.99	0.38921
100	17	14.24	0.65023
Combined P-value for all tests (Using KS method)			0.16555

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	39.13	0.86649
2	50	64.54	0.08100
3	50	67.19	0.05269
4	50	54.08	0.32152
5	50	53.20	0.35192
6	50	40.48	0.82956
7	50	42.87	0.75237
8	50	46.15	0.62876
9	50	54.39	0.31094
10	50	64.52	0.08133
11	50	52.04	0.39433
12	50	38.70	0.87715
13	50	60.04	0.15633
14	50	42.73	0.75736
15	50	50.95	0.43585
16	50	51.55	0.41295
17	50	40.50	0.82881
18	50	68.69	0.04077
19	50	48.25	0.54379
20	50	33.24	0.96734
21	50	46.30	0.62262
22	50	53.60	0.33811
23	50	60.12	0.15460
24	50	56.25	0.25236

25	50	39.69	0.85166
26	50	45.66	0.64814
27	50	36.43	0.92435
28	50	43.47	0.73104
29	50	78.49	0.00618
30	50	39.45	0.85800
31	50	43.93	0.71431
32	50	55.96	0.26105
33	50	54.97	0.29194
34	50	72.07	0.02217
35	50	51.89	0.40015
36	50	59.67	0.16432
37	50	56.47	0.24596
38	50	61.28	0.13163
39	50	61.74	0.12334
40	50	39.24	0.86361
41	50	67.58	0.04934
42	50	34.85	0.94884
43	50	43.57	0.72747
44	50	57.48	0.21782
45	50	47.53	0.57302
46	50	59.23	0.17427
47	50	42.10	0.77887
48	50	43.44	0.73228
49	50	67.58	0.04935
50	50	45.50	0.65426
51	50	49.93	0.47622
52	50	51.85	0.40159
53	50	80.29	0.00421
54	50	67.50	0.05004
55	50	58.08	0.20211
56	50	51.75	0.40540
57	50	27.76	0.99548
58	50	37.43	0.90532
59	50	38.72	0.87661
60	50	48.16	0.54752
61	50	46.75	0.60464
62	50	54.74	0.29948
63	50	49.12	0.50866
64	50	60.64	0.14397
65	50	64.35	0.08350
66	50	90.64	0.00038
67	50	30.25	0.98774
68	50	68.48	0.04234
69	50	56.60	0.24228
70	50	43.23	0.73976
71	50	47.24	0.58473
72	50	49.97	0.47452
73	50	41.47	0.79924
74	50	31.29	0.98237
75	50	51.18	0.42719
76	50	38.99	0.86995
77	50	51.50	0.41474
78	50	37.90	0.89544
79	50	28.62	0.99348

80	50	61.08	0.13553
81	50	44.53	0.69172
82	50	54.91	0.29379
83	50	75.24	0.01201
84	50	42.90	0.75148
85	50	38.51	0.88168
86	50	62.42	0.11167
87	50	50.89	0.43837
88	50	43.15	0.74259
89	50	42.32	0.77151
90	50	54.96	0.29238
91	50	64.12	0.08642
92	50	47.53	0.57300
93	50	48.66	0.52715
94	50	49.48	0.49432
95	50	56.67	0.24036
96	50	54.44	0.30930
97	50	64.86	0.07706
98	50	59.07	0.17788
99	50	41.35	0.80302
100	50	66.70	0.05719
Combined P-value for all tests			0.49315

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	19.86	0.06973
2	12	12.64	0.39567
3	12	2.56	0.99795
4	12	8.81	0.71913
5	12	12.23	0.42753
6	12	11.73	0.46752
7	12	4.51	0.97239
8	12	19.72	0.07252
9	12	23.86	0.02127
10	12	22.71	0.03033
11	12	10.69	0.55585
12	12	8.33	0.75898
13	12	5.33	0.94622
14	12	5.50	0.93900
15	12	18.98	0.08897
16	12	5.74	0.92856

17	12	10.54	0.56828
18	12	8.77	0.72242
19	12	10.71	0.55416
20	12	9.65	0.64626
21	12	6.10	0.91119
22	12	12.78	0.38542
23	12	15.12	0.23490
24	12	7.87	0.79521
25	12	14.80	0.25280
26	12	13.90	0.30701
27	12	10.09	0.60809
28	12	8.61	0.73575
29	12	16.34	0.17604
30	12	13.54	0.33118
31	12	7.96	0.78817
32	12	6.16	0.90778
33	12	9.60	0.65143
34	12	13.58	0.32840
35	12	18.04	0.11459
36	12	6.24	0.90344
37	12	8.10	0.77737
38	12	8.46	0.74825
39	12	19.26	0.08235
40	12	11.85	0.45746
41	12	15.42	0.21946
42	12	14.75	0.25513
43	12	10.74	0.55165
44	12	9.16	0.68955
45	12	17.38	0.13593
46	12	10.45	0.57653
47	12	7.28	0.83849
48	12	8.00	0.78487
49	12	10.01	0.61499
50	12	4.84	0.96302
51	12	12.28	0.42378
52	12	4.22	0.97903
53	12	11.61	0.47736
54	12	19.57	0.07566
55	12	21.90	0.03864
56	12	8.22	0.76771
57	12	10.56	0.56670
58	12	16.61	0.16478
59	12	12.91	0.37529
60	12	11.51	0.48599
61	12	10.29	0.59017
62	12	19.55	0.07603
63	12	10.96	0.53197
64	12	3.56	0.99017
65	12	10.23	0.59599
66	12	6.36	0.89688
67	12	14.50	0.26973
68	12	22.46	0.03265
69	12	6.67	0.87889
70	12	9.36	0.67182
71	12	8.56	0.73991

72	12	12.44	0.41097
73	12	8.30	0.76096
74	12	8.99	0.70416
75	12	3.44	0.99151
76	12	10.99	0.52974
77	12	24.18	0.01922
78	12	15.18	0.23162
79	12	14.46	0.27230
80	12	21.35	0.04552
81	12	6.55	0.88568
82	12	6.70	0.87694
83	12	4.52	0.97222
84	12	16.58	0.16619
85	12	9.09	0.69526
86	12	15.41	0.21990
87	12	13.60	0.32723
88	12	8.86	0.71448
89	12	18.69	0.09631
90	12	9.05	0.69824
91	12	8.92	0.70982
92	12	6.27	0.90186
93	12	13.98	0.30196
94	12	6.41	0.89410
95	12	5.65	0.93248
96	12	15.90	0.19565
97	12	15.77	0.20192
98	12	7.84	0.79717
99	12	22.62	0.03117
100	12	10.24	0.59488
Combined P-value for all tests (Using KS method)			0.35460

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	9.38	0.66994
2	12	11.35	0.49937
3	12	13.22	0.35327
4	12	4.48	0.97310
5	12	8.12	0.77538
6	12	9.00	0.70319
7	12	6.35	0.89746
8	12	2.79	0.99687
9	12	12.32	0.42011
10	12	8.40	0.75287
11	12	17.71	0.12488
12	12	3.58	0.98988
13	12	9.24	0.68252
14	12	7.68	0.80947
15	12	17.41	0.13466
16	12	15.76	0.20252

17	12	16.78	0.15799
18	12	12.72	0.38960
19	12	7.37	0.83208
20	12	14.19	0.28871
21	12	5.76	0.92779
22	12	18.42	0.10347
23	12	12.52	0.40520
24	12	9.77	0.63571
25	12	10.43	0.57836
26	12	12.22	0.42827
27	12	11.72	0.46838
28	12	11.97	0.44812
29	12	13.70	0.32022
30	12	15.72	0.20450
31	12	6.26	0.90238
32	12	6.97	0.85980
33	12	5.29	0.94759
34	12	4.16	0.98044
35	12	23.38	0.02469
36	12	6.67	0.87863
37	12	19.75	0.07192
38	12	11.91	0.45284
39	12	18.05	0.11433
40	12	3.67	0.98869
41	12	21.62	0.04201
42	12	17.28	0.13936
43	12	8.97	0.70559
44	12	6.44	0.89216
45	12	12.46	0.40920
46	12	9.94	0.62089
47	12	3.72	0.98793
48	12	21.56	0.04279
49	12	6.02	0.91485
50	12	18.49	0.10162
51	12	5.77	0.92719
52	12	8.97	0.70559
53	12	15.50	0.21538
54	12	7.82	0.79900
55	12	18.04	0.11459
56	12	17.32	0.13798
57	12	8.31	0.76045
58	12	14.43	0.27404
59	12	16.44	0.17183
60	12	9.91	0.62393
61	12	23.72	0.02219
62	12	27.21	0.00721
63	12	20.34	0.06093
64	12	15.12	0.23506
65	12	14.17	0.29019
66	12	11.81	0.46093
67	12	12.32	0.42028
68	12	18.98	0.08894
69	12	10.19	0.59922
70	12	3.97	0.98389
71	12	11.26	0.50668

72	12	12.92	0.37482
73	12	11.02	0.52752
74	12	4.27	0.97812
75	12	21.23	0.04705
76	12	7.93	0.79033
77	12	13.98	0.30210
78	12	27.63	0.00626
79	12	17.08	0.14674
80	12	13.74	0.31763
81	12	7.03	0.85565
82	12	12.05	0.44169
83	12	5.83	0.92444
84	12	12.08	0.43961
85	12	8.26	0.76430
86	12	7.59	0.81607
87	12	10.88	0.53906
88	12	7.75	0.80465
89	12	6.58	0.88420
90	12	13.78	0.31498
91	12	12.45	0.41040
92	12	16.39	0.17402
93	12	11.43	0.49264
94	12	10.78	0.54769
95	12	12.80	0.38360
96	12	6.19	0.90631
97	12	18.72	0.09557
98	12	16.14	0.18473
99	12	17.25	0.14029
100	12	6.27	0.90192
Combined P-value for all tests (Using KS method)			0.54970

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)	0.96171	1.00000
Opening Score (Dealer)	0.16555	0.82774
Dealer's Final Score	0.49315	1.00000
Player Cards Rank	0.35460	1.00000
Dealer Cards Rank	0.54970	1.00000
Combined P-Value using Holm's Method		0.82774

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.

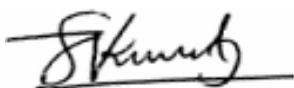
We conclude that the Random Number Generator (RNG) is working correctly.

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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Date: 04 May, 2021

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.