



Blackjack Cards Analysis – December 2020

The Directors

GVC Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **December 01, 2020 to December 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	16.46	0.49148
2	17	21.91	0.18836
3	17	14.51	0.63066
4	17	12.83	0.74725
5	17	11.39	0.83551
6	17	18.45	0.36129
7	17	15.25	0.57764
8	17	8.46	0.95565
9	17	13.99	0.66785
10	17	20.80	0.23557
11	17	9.27	0.93155
12	17	8.11	0.96412
13	17	19.90	0.27918
14	17	10.26	0.89250
15	17	13.87	0.67603
16	17	10.92	0.86066
17	17	21.37	0.21022
18	17	15.58	0.55392
19	17	20.87	0.23214
20	17	36.90	0.00348
21	17	14.02	0.66600
22	17	22.69	0.15948
23	17	24.39	0.10915
24	17	12.68	0.75741

25	17	21.03	0.22476
26	17	19.31	0.31113
27	17	13.24	0.72024
28	17	18.26	0.37267
29	17	11.34	0.83854
30	17	18.86	0.33689
31	17	9.85	0.90996
32	17	11.86	0.80848
33	17	24.27	0.11235
34	17	23.18	0.14354
35	17	24.74	0.10070
36	17	11.42	0.83380
37	17	17.92	0.39362
38	17	18.92	0.33311
39	17	22.30	0.17346
40	17	15.20	0.58093
41	17	14.56	0.62699
42	17	10.80	0.86692
43	17	14.59	0.62497
44	17	17.58	0.41559
45	17	27.24	0.05471
46	17	20.00	0.27437
47	17	19.39	0.30638
48	17	17.26	0.43679
49	17	16.23	0.50787
50	17	31.83	0.01581
51	17	14.62	0.62251
52	17	14.84	0.60693
53	17	22.81	0.15560
54	17	19.88	0.28042
55	17	14.87	0.60486
56	17	17.41	0.42727
57	17	25.08	0.09295
58	17	17.51	0.42044
59	17	11.86	0.80848
60	17	7.60	0.97431
61	17	20.34	0.25720
62	17	12.26	0.78399
63	17	12.10	0.79403
64	17	23.64	0.12949
65	17	27.48	0.05144
66	17	16.40	0.49550
67	17	12.63	0.76069
68	17	12.72	0.75449
69	17	19.72	0.28867
70	17	8.52	0.95426
71	17	14.63	0.62182
72	17	34.19	0.00792
73	17	26.84	0.06043
74	17	11.75	0.81493
75	17	14.62	0.62305
76	17	28.76	0.03683
77	17	10.26	0.89229
78	17	10.11	0.89903
79	17	17.13	0.44578

80	17	14.12	0.65824
81	17	14.06	0.66310
82	17	33.43	0.00995
83	17	25.90	0.07632
84	17	8.07	0.96492
85	17	18.42	0.36287
86	17	15.83	0.53569
87	17	14.17	0.65501
88	17	23.48	0.13429
89	17	14.03	0.66472
90	17	18.64	0.34940
91	17	22.88	0.15305
92	17	10.41	0.88549
93	17	13.53	0.70026
94	17	24.27	0.11231
95	17	16.97	0.45612
96	17	19.12	0.32142
97	17	21.79	0.19283
98	17	14.89	0.60349
99	17	18.59	0.35262
100	17	18.15	0.37925
Combined P-value for all tests (Using KS method)			0.98878

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	11.91	0.80562
2	17	20.56	0.24664
3	17	9.34	0.92900
4	17	21.21	0.21715
5	17	30.67	0.02187
6	17	10.50	0.88123
7	17	16.94	0.45842
8	17	24.96	0.09553
9	17	12.45	0.77243
10	17	17.21	0.44022
11	17	26.22	0.07058
12	17	13.77	0.68309
13	17	28.86	0.03582
14	17	20.28	0.26029
15	17	8.14	0.96337
16	17	15.10	0.58814
17	17	16.12	0.51518
18	17	7.90	0.96871
19	17	19.05	0.32546
20	17	21.39	0.20931
21	17	38.60	0.00203
22	17	23.07	0.14704
23	17	14.02	0.66575
24	17	9.52	0.92258

25	17	20.51	0.24910
26	17	24.86	0.09798
27	17	23.15	0.14438
28	17	23.20	0.14293
29	17	8.93	0.94249
30	17	20.64	0.24267
31	17	14.61	0.62363
32	17	18.61	0.35155
33	17	24.05	0.11804
34	17	15.81	0.53725
35	17	9.53	0.92221
36	17	8.46	0.95562
37	17	12.43	0.77368
38	17	13.57	0.69703
39	17	21.68	0.19740
40	17	8.78	0.94678
41	17	25.83	0.07752
42	17	28.34	0.04108
43	17	31.13	0.01927
44	17	15.34	0.57109
45	17	15.58	0.55398
46	17	14.47	0.63363
47	17	10.75	0.86946
48	17	10.92	0.86072
49	17	15.34	0.57095
50	17	22.93	0.15148
51	17	18.69	0.34670
52	17	12.75	0.75297
53	17	21.10	0.22192
54	17	25.92	0.07584
55	17	14.32	0.64462
56	17	22.39	0.17035
57	17	27.88	0.04641
58	17	9.52	0.92243
59	17	22.69	0.15956
60	17	14.21	0.65229
61	17	16.96	0.45735
62	17	13.78	0.68241
63	17	21.14	0.22003
64	17	19.92	0.27811
65	17	17.56	0.41689
66	17	16.35	0.49946
67	17	23.29	0.14005
68	17	12.69	0.75695
69	17	7.96	0.96741
70	17	11.26	0.84272
71	17	24.34	0.11046
72	17	17.78	0.40259
73	17	22.96	0.15065
74	17	14.30	0.64587
75	17	14.36	0.64133
76	17	27.74	0.04809
77	17	9.38	0.92763
78	17	11.51	0.82905
79	17	15.51	0.55872

80	17	12.32	0.78039
81	17	21.44	0.20708
82	17	15.65	0.54860
83	17	13.38	0.71033
84	17	13.58	0.69652
85	17	19.33	0.31007
86	17	28.66	0.03775
87	17	8.17	0.96279
88	17	7.71	0.97230
89	17	10.83	0.86528
90	17	21.50	0.20466
91	17	15.57	0.55447
92	17	19.96	0.27611
93	17	18.69	0.34633
94	17	9.74	0.91431
95	17	11.98	0.80115
96	17	8.18	0.96243
97	17	25.54	0.08329
98	17	14.43	0.63661
99	17	13.13	0.72753
100	17	22.08	0.18149
Combined P-value for all tests (Using KS method)			0.35142

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	52.69	0.37031
2	50	50.22	0.46479
3	50	54.04	0.32280
4	50	67.77	0.04784
5	50	46.40	0.61871
6	50	51.97	0.39722
7	50	57.02	0.23025
8	50	39.84	0.84764
9	50	61.37	0.13009
10	50	48.50	0.53383
11	50	56.43	0.24707
12	50	29.14	0.99198
13	50	44.47	0.69407
14	50	48.35	0.53987
15	50	43.03	0.74696
16	50	45.52	0.65369
17	50	39.65	0.85288
18	50	61.84	0.12157
19	50	48.34	0.54040
20	50	51.19	0.42685
21	50	41.14	0.80979
22	50	62.66	0.10789
23	50	39.09	0.86749
24	50	47.29	0.58285

25	50	49.09	0.50997
26	50	35.08	0.94578
27	50	51.91	0.39920
28	50	33.08	0.96880
29	50	68.56	0.04175
30	50	45.43	0.65698
31	50	47.04	0.59303
32	50	66.87	0.05564
33	50	61.45	0.12852
34	50	50.86	0.43944
35	50	49.35	0.49944
36	50	63.19	0.09968
37	50	70.66	0.02872
38	50	52.10	0.39209
39	50	41.38	0.80212
40	50	35.89	0.93346
41	50	55.79	0.26633
42	50	42.74	0.75701
43	50	66.92	0.05514
44	50	65.79	0.06638
45	50	53.52	0.34067
46	50	34.06	0.95870
47	50	50.67	0.44703
48	50	51.83	0.40217
49	50	44.90	0.67778
50	50	49.74	0.48395
51	50	44.03	0.71079
52	50	48.86	0.51913
53	50	63.08	0.10132
54	50	51.64	0.40965
55	50	61.07	0.13571
56	50	44.16	0.70577
57	50	51.76	0.40490
58	50	42.54	0.76382
59	50	70.33	0.03052
60	50	50.36	0.45921
61	50	54.66	0.30215
62	50	58.49	0.19193
63	50	53.88	0.32814
64	50	52.89	0.36309
65	50	53.62	0.33726
66	50	57.12	0.22748
67	50	58.04	0.20310
68	50	63.83	0.09044
69	50	42.83	0.75392
70	50	38.17	0.88941
71	50	52.72	0.36937
72	50	44.57	0.69025
73	50	50.28	0.46239
74	50	48.93	0.51647
75	50	62.66	0.10782
76	50	54.87	0.29530
77	50	70.20	0.03123
78	50	47.65	0.56817
79	50	65.38	0.07095

80	50	52.57	0.37493
81	50	50.82	0.44110
82	50	53.90	0.32751
83	50	57.90	0.20680
84	50	38.01	0.89294
85	50	41.46	0.79966
86	50	47.06	0.59190
87	50	45.10	0.66996
88	50	58.45	0.19287
89	50	57.49	0.21762
90	50	62.21	0.11523
91	50	53.58	0.33880
92	50	52.10	0.39229
93	50	36.80	0.91764
94	50	43.04	0.74664
95	50	62.71	0.10702
96	50	49.57	0.49054
97	50	40.85	0.81846
98	50	46.45	0.61649
99	50	39.31	0.86182
100	50	45.52	0.65335
Combined P-value for all tests			0.38210

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	16.93	0.15236
2	12	15.35	0.22301
3	12	16.23	0.18102
4	12	10.23	0.59548
5	12	11.49	0.48720
6	12	12.51	0.40586
7	12	11.46	0.49009
8	12	19.31	0.08124
9	12	7.37	0.83218
10	12	15.70	0.20554
11	12	16.34	0.17600
12	12	6.02	0.91514
13	12	9.58	0.65270
14	12	14.60	0.26429
15	12	9.11	0.69377
16	12	10.40	0.58107

17	12	10.67	0.55741
18	12	26.05	0.01057
19	12	17.23	0.14113
20	12	10.25	0.59447
21	12	9.19	0.68656
22	12	8.34	0.75815
23	12	8.01	0.78442
24	12	16.38	0.17452
25	12	5.43	0.94220
26	12	10.78	0.54790
27	12	6.32	0.89931
28	12	5.63	0.93351
29	12	10.29	0.59092
30	12	11.72	0.46855
31	12	24.66	0.01650
32	12	17.81	0.12155
33	12	13.40	0.34046
34	12	12.85	0.37997
35	12	15.14	0.23362
36	12	4.06	0.98233
37	12	7.28	0.83889
38	12	6.65	0.87995
39	12	9.35	0.67282
40	12	16.04	0.18927
41	12	12.18	0.43151
42	12	6.49	0.88942
43	12	13.54	0.33075
44	12	14.71	0.25777
45	12	17.93	0.11785
46	12	14.62	0.26311
47	12	16.06	0.18835
48	12	17.45	0.13354
49	12	12.03	0.44301
50	12	12.94	0.37317
51	12	12.41	0.41320
52	12	12.53	0.40387
53	12	9.51	0.65925
54	12	14.15	0.29154
55	12	9.46	0.66328
56	12	8.47	0.74774
57	12	5.78	0.92700
58	12	10.45	0.57634
59	12	16.51	0.16885
60	12	8.14	0.77443
61	12	14.46	0.27221
62	12	16.01	0.19084
63	12	4.24	0.97880
64	12	15.31	0.22496
65	12	10.87	0.54001
66	12	17.64	0.12711
67	12	4.99	0.95841
68	12	13.89	0.30748
69	12	12.09	0.43845
70	12	20.24	0.06266
71	12	7.52	0.82146

72	12	23.90	0.02101
73	12	7.90	0.79256
74	12	2.85	0.99653
75	12	10.28	0.59180
76	12	16.22	0.18140
77	12	11.44	0.49138
78	12	14.35	0.27909
79	12	7.06	0.85366
80	12	8.95	0.70679
81	12	8.58	0.73829
82	12	23.16	0.02639
83	12	14.35	0.27893
84	12	5.52	0.93853
85	12	6.86	0.86678
86	12	15.30	0.22537
87	12	14.60	0.26408
88	12	10.98	0.53062
89	12	12.35	0.41796
90	12	11.89	0.45433
91	12	11.75	0.46576
92	12	8.55	0.74045
93	12	17.24	0.14085
94	12	11.11	0.51972
95	12	11.95	0.44970
96	12	16.29	0.17834
97	12	15.12	0.23511
98	12	8.64	0.73375
99	12	14.23	0.28609
100	12	13.30	0.34741
Combined P-value for all tests (Using KS method)			0.61881

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	27.33	0.00692
2	12	11.95	0.44986
3	12	10.14	0.60350
4	12	16.83	0.15595
5	12	10.25	0.59369
6	12	19.77	0.07160
7	12	27.15	0.00736
8	12	11.29	0.50407
9	12	6.04	0.91385
10	12	10.01	0.61543
11	12	19.18	0.08428
12	12	13.85	0.31026
13	12	6.39	0.89505
14	12	12.47	0.40902
15	12	6.01	0.91568
16	12	12.52	0.40487

17	12	17.58	0.12905
18	12	14.87	0.24885
19	12	4.84	0.96317
20	12	12.23	0.42739
21	12	4.87	0.96206
22	12	11.80	0.46187
23	12	6.97	0.85946
24	12	9.01	0.70242
25	12	13.99	0.30160
26	12	18.66	0.09718
27	12	9.80	0.63368
28	12	10.22	0.59684
29	12	18.38	0.10452
30	12	8.65	0.73216
31	12	10.04	0.61228
32	12	11.30	0.50357
33	12	8.15	0.77314
34	12	7.37	0.83194
35	12	15.49	0.21553
36	12	8.95	0.70720
37	12	13.29	0.34860
38	12	11.10	0.52003
39	12	6.06	0.91292
40	12	21.54	0.04304
41	12	11.35	0.49902
42	12	12.45	0.40994
43	12	18.11	0.11251
44	12	12.45	0.41025
45	12	15.78	0.20152
46	12	8.13	0.77521
47	12	7.64	0.81259
48	12	7.69	0.80856
49	12	9.69	0.64279
50	12	10.40	0.58074
51	12	13.43	0.33830
52	12	12.95	0.37269
53	12	25.77	0.01156
54	12	4.79	0.96463
55	12	8.34	0.75770
56	12	5.45	0.94124
57	12	15.65	0.20760
58	12	5.37	0.94455
59	12	21.27	0.04654
60	12	12.26	0.42487
61	12	15.86	0.19764
62	12	4.57	0.97077
63	12	7.36	0.83294
64	12	12.89	0.37723
65	12	15.21	0.23036
66	12	8.95	0.70737
67	12	13.57	0.32873
68	12	10.43	0.57829
69	12	4.02	0.98315
70	12	9.02	0.70139
71	12	21.09	0.04902

72	12	14.83	0.25075
73	12	13.72	0.31908
74	12	11.35	0.49935
75	12	9.19	0.68645
76	12	14.10	0.29437
77	12	8.91	0.71077
78	12	14.86	0.24918
79	12	27.56	0.00642
80	12	14.26	0.28417
81	12	16.20	0.18207
82	12	16.85	0.15544
83	12	11.52	0.48490
84	12	11.66	0.47366
85	12	7.66	0.81126
86	12	8.30	0.76093
87	12	13.51	0.33298
88	12	6.89	0.86474
89	12	14.40	0.27594
90	12	23.53	0.02353
91	12	9.31	0.67587
92	12	7.84	0.79752
93	12	11.09	0.52155
94	12	11.30	0.50358
95	12	9.50	0.65988
96	12	7.64	0.81251
97	12	6.11	0.91029
98	12	16.17	0.18369
99	12	10.43	0.57792
100	12	17.04	0.14811
Combined P-value for all tests (Using KS method)			1.00000

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)	0.98878	1.00000
Opening Score (Dealer)	0.35142	1.00000
Dealer's Final Score	0.38210	1.00000
Player Cards Rank	0.61881	1.00000
Dealer Cards Rank	1.00000	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.

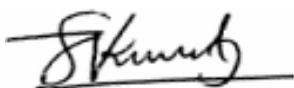
We conclude that the Random Number Generator (RNG) is working correctly.

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:



Kiren Sreekumar
Principal Consultant
iTech Labs Australia
Date: 04 May, 2021

Signed:



Gyulserian Hyussein
Senior Consultant
iTech Labs Australia
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.