



## Blackjack Cards Analysis – May 2023

### The Directors

Entain Plc

This is to confirm that iTech Labs has examined the game logs for blackjack games for the period **May 01, 2023 to May 31, 2023** 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	11.61	0.82319
2	17	17.43	0.42539
3	17	26.40	0.06740
4	17	28.13	0.04340
5	17	21.21	0.21716
6	17	22.42	0.16905
7	17	16.86	0.46367
8	17	15.80	0.53799
9	17	12.07	0.79578
10	17	14.71	0.61631
11	17	15.31	0.57306
12	17	26.13	0.07205
13	17	16.33	0.50061
14	17	17.21	0.44040
15	17	8.22	0.96153
16	17	9.01	0.93998
17	17	25.81	0.07793
18	17	10.25	0.89293
19	17	12.84	0.74685
20	17	24.44	0.10805
21	17	12.97	0.73818
22	17	20.88	0.23176
23	17	15.51	0.55892
24	17	20.52	0.24832

25	17	16.61	0.48075
26	17	25.39	0.08633
27	17	13.62	0.69383
28	17	10.93	0.86042
29	17	21.10	0.22165
30	17	14.14	0.65701
31	17	21.70	0.19650
32	17	17.29	0.43481
33	17	15.16	0.58427
34	17	10.76	0.86883
35	17	17.24	0.43800
36	17	17.58	0.41578
37	17	21.39	0.20942
38	17	10.87	0.86311
39	17	13.56	0.69822
40	17	18.46	0.36064
41	17	10.67	0.87342
42	17	5.84	0.99420
43	17	13.75	0.68474
44	17	29.54	0.02986
45	17	15.76	0.54115
46	17	15.71	0.54453
47	17	5.92	0.99372
48	17	16.71	0.47404
49	17	14.21	0.65230
50	17	13.58	0.69687
51	17	12.23	0.78578
52	17	12.34	0.77927
53	17	15.75	0.54187
54	17	12.85	0.74613
55	17	15.93	0.52913
56	17	12.19	0.78869
57	17	10.70	0.87185
58	17	15.39	0.56737
59	17	19.37	0.30768
60	17	14.58	0.62566
61	17	23.27	0.14065
62	17	25.27	0.08877
63	17	26.38	0.06775
64	17	18.48	0.35892
65	17	13.70	0.68797
66	17	17.58	0.41594
67	17	16.17	0.51202
68	17	11.27	0.84219
69	17	12.22	0.78684
70	17	12.43	0.77314
71	17	12.26	0.78399
72	17	16.07	0.51881
73	17	13.16	0.72552
74	17	24.72	0.10112
75	17	9.31	0.93004
76	17	15.56	0.55547
77	17	18.14	0.38011
78	17	17.18	0.44256
79	17	19.81	0.28427
80	17	7.98	0.96702

81	17	31.17	0.01905
82	17	26.55	0.06496
83	17	11.61	0.82333
84	17	17.96	0.39156
85	17	18.99	0.32927
86	17	15.10	0.58800
87	17	12.91	0.74243
88	17	28.07	0.04417
89	17	20.40	0.25433
90	17	12.34	0.77898
91	17	20.62	0.24369
92	17	20.35	0.25677
93	17	12.51	0.76835
94	17	15.98	0.52554
95	17	12.37	0.77713
96	17	24.26	0.11263
97	17	10.97	0.85800
98	17	16.83	0.46625
99	17	7.21	0.98065
100	17	13.31	0.71523
Combined P-value for all tests (Using KS method)			0.30313

*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	20.86	0.23262
2	17	14.12	0.65846
3	17	20.61	0.24419
4	17	13.73	0.68590
5	17	24.33	0.11087
6	17	16.71	0.47405
7	17	12.79	0.75022
8	17	15.59	0.55309
9	17	14.57	0.62655
10	17	14.75	0.61330
11	17	13.76	0.68426
12	17	11.14	0.84901
13	17	12.36	0.77781
14	17	18.18	0.37746
15	17	13.21	0.72210
16	17	10.11	0.89914
17	17	12.08	0.79542
18	17	8.80	0.94640
19	17	21.22	0.21670
20	17	17.02	0.45285
21	17	10.01	0.90316
22	17	9.03	0.93931
23	17	9.07	0.93799
24	17	8.95	0.94187
25	17	12.26	0.78435
26	17	22.18	0.17790

27	17	21.12	0.22087
28	17	14.36	0.64178
29	17	24.41	0.10861
30	17	22.18	0.17775
31	17	11.68	0.81928
32	17	24.53	0.10579
33	17	10.87	0.86345
34	17	14.98	0.59721
35	17	9.22	0.93314
36	17	15.69	0.54580
37	17	13.61	0.69414
38	17	16.05	0.52053
39	17	13.87	0.67608
40	17	8.70	0.94918
41	17	18.12	0.38126
42	17	11.91	0.80581
43	17	15.02	0.59372
44	17	16.00	0.52410
45	17	11.98	0.80148
46	17	22.63	0.16153
47	17	17.80	0.40180
48	17	13.97	0.66916
49	17	20.13	0.26751
50	17	11.12	0.85045
51	17	19.57	0.29691
52	17	30.65	0.02202
53	17	14.12	0.65869
54	17	14.87	0.60516
55	17	21.80	0.19265
56	17	21.72	0.19565
57	17	10.58	0.87778
58	17	14.05	0.66347
59	17	23.31	0.13944
60	17	22.89	0.15273
61	17	14.60	0.62400
62	17	13.01	0.73580
63	17	15.46	0.56247
64	17	18.81	0.33954
65	17	7.74	0.97182
66	17	13.57	0.69719
67	17	12.92	0.74177
68	17	11.20	0.84597
69	17	10.96	0.85864
70	17	13.35	0.71270
71	17	27.94	0.04568
72	17	11.44	0.83294
73	17	22.96	0.15046
74	17	15.33	0.57193
75	17	7.11	0.98215
76	17	21.95	0.18684
77	17	11.03	0.85525
78	17	15.71	0.54419
79	17	20.58	0.24579
80	17	22.19	0.17748
81	17	15.11	0.58792
82	17	16.94	0.45870

83	17	15.46	0.56224
84	17	12.03	0.79832
85	17	18.02	0.38733
86	17	5.91	0.99377
87	17	18.18	0.37749
88	17	4.79	0.99829
89	17	11.47	0.83113
90	17	18.90	0.33401
91	17	24.42	0.10852
92	17	11.07	0.85314
93	17	17.60	0.41428
94	17	31.68	0.01648
95	17	10.46	0.88323
96	17	13.71	0.68778
97	17	18.60	0.35224
98	17	22.89	0.15287
99	17	27.77	0.04765
100	17	19.63	0.29369
Combined P-value for all tests (Using KS method)			0.04963

*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	54.40	0.31065
2	50	44.11	0.70776
3	50	40.20	0.83771
4	50	49.77	0.48274
5	50	41.68	0.79264
6	50	55.45	0.27689
7	50	63.68	0.09251
8	50	51.29	0.42291
9	50	47.34	0.58072
10	50	51.59	0.41137
11	50	36.75	0.91868
12	50	47.29	0.58275
13	50	42.75	0.75663
14	50	40.35	0.83333
15	50	38.37	0.88486
16	50	45.29	0.66259
17	50	42.59	0.76223
18	50	50.83	0.44074
19	50	47.17	0.58764
20	50	43.46	0.73162
21	50	37.63	0.90133
22	50	35.83	0.93446
23	50	60.68	0.14326
24	50	48.83	0.52045
25	50	47.89	0.55848
26	50	39.33	0.86120
27	50	45.72	0.64580
28	50	48.76	0.52337

29	50	40.73	0.82214
30	50	52.74	0.36848
31	50	44.09	0.70838
32	50	35.21	0.94384
33	50	40.06	0.84151
34	50	62.28	0.11403
35	50	58.62	0.18879
36	50	41.59	0.79549
37	50	44.83	0.68028
38	50	41.80	0.78884
39	50	48.84	0.52013
40	50	38.78	0.87514
41	50	54.64	0.30284
42	50	52.54	0.37587
43	50	41.12	0.81031
44	50	49.72	0.48437
45	50	37.73	0.89921
46	50	60.24	0.15228
47	50	54.88	0.29501
48	50	32.15	0.97660
49	50	56.31	0.25068
50	50	50.05	0.47133
51	50	33.38	0.96598
52	50	40.21	0.83735
53	50	41.93	0.78434
54	50	43.28	0.73810
55	50	63.52	0.09488
56	50	84.61	0.00161
57	50	56.26	0.25227
58	50	62.61	0.10858
59	50	45.64	0.64878
60	50	72.82	0.01924
61	50	42.21	0.77526
62	50	59.43	0.16964
63	50	45.11	0.66935
64	50	43.84	0.71756
65	50	51.83	0.40239
66	50	36.45	0.92406
67	50	52.45	0.37926
68	50	58.36	0.19496
69	50	40.18	0.83810
70	50	42.53	0.76420
71	50	66.82	0.05605
72	50	67.82	0.04740
73	50	48.70	0.52579
74	50	51.27	0.42358
75	50	43.89	0.71574
76	50	43.29	0.73771
77	50	45.02	0.67314
78	50	59.06	0.17817
79	50	60.70	0.14291
80	50	44.51	0.69263
81	50	40.47	0.82992
82	50	27.09	0.99664
83	50	49.13	0.50844
84	50	61.61	0.12568

85	50	62.26	0.11436
86	50	47.16	0.58799
87	50	56.27	0.25184
88	50	55.68	0.26951
89	50	56.93	0.23281
90	50	34.79	0.94972
91	50	65.43	0.07037
92	50	47.01	0.59403
93	50	57.44	0.21879
94	50	50.15	0.46753
95	50	43.81	0.71882
96	50	72.56	0.02022
97	50	44.17	0.70555
98	50	46.34	0.62105
99	50	55.70	0.26912
100	50	45.95	0.63653
Combined P-value for all tests			0.24879

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	15.94	0.19409
2	12	14.71	0.25776
3	12	8.89	0.71218
4	12	7.29	0.83801
5	12	12.96	0.37220
6	12	22.12	0.03619
7	12	6.15	0.90812
8	12	8.07	0.78000
9	12	11.17	0.51401
10	12	12.35	0.41820
11	12	12.76	0.38692
12	12	10.54	0.56841
13	12	11.80	0.46214
14	12	12.24	0.42671
15	12	10.50	0.57236
16	12	15.67	0.20705
17	12	15.75	0.20280
18	12	10.01	0.61491
19	12	10.88	0.53911
20	12	10.07	0.61005
21	12	12.14	0.43487
22	12	13.98	0.30190

23	12	20.77	0.05392
24	12	16.08	0.18772
25	12	21.83	0.03946
26	12	7.05	0.85416
27	12	7.55	0.81948
28	12	13.58	0.32855
29	12	6.73	0.87468
30	12	9.48	0.66148
31	12	14.24	0.28573
32	12	7.87	0.79551
33	12	11.74	0.46683
34	12	19.12	0.08566
35	12	14.21	0.28750
36	12	9.19	0.68656
37	12	13.30	0.34748
38	12	6.71	0.87588
39	12	12.35	0.41815
40	12	10.36	0.58441
41	12	16.41	0.17311
42	12	16.78	0.15793
43	12	10.15	0.60280
44	12	11.30	0.50345
45	12	17.90	0.11882
46	12	6.71	0.87646
47	12	14.70	0.25841
48	12	12.23	0.42707
49	12	21.98	0.03771
50	12	8.47	0.74724
51	12	10.49	0.57323
52	12	6.36	0.89686
53	12	8.19	0.76974
54	12	5.01	0.95776
55	12	19.56	0.07595
56	12	16.10	0.18667
57	12	8.68	0.72999
58	12	9.40	0.66873
59	12	16.75	0.15914
60	12	4.55	0.97145
61	12	15.14	0.23394
62	12	24.55	0.01710
63	12	15.58	0.21130
64	12	13.00	0.36875
65	12	5.42	0.94235
66	12	17.61	0.12817
67	12	16.32	0.17687
68	12	18.83	0.09278
69	12	13.67	0.32259
70	12	14.31	0.28119
71	12	13.09	0.36282
72	12	11.50	0.48651
73	12	14.76	0.25469
74	12	13.86	0.30981
75	12	8.20	0.76915
76	12	7.73	0.80556
77	12	17.13	0.14461
78	12	14.31	0.28139



79	12	11.20	0.51177
80	12	7.72	0.80634
81	12	16.87	0.15471
82	12	10.31	0.58890
83	12	12.38	0.41530
84	12	12.18	0.43149
85	12	6.22	0.90437
86	12	15.05	0.23873
87	12	7.06	0.85350
88	12	7.58	0.81675
89	12	11.24	0.50846
90	12	9.40	0.66884
91	12	18.47	0.10215
92	12	5.58	0.93579
93	12	26.25	0.00988
94	12	5.68	0.93126
95	12	10.66	0.55812
96	12	4.55	0.97126
97	12	9.30	0.67707
98	12	12.02	0.44401
99	12	9.90	0.62441
100	12	16.55	0.16723
Combined P-value for all tests (Using KS method)			0.90450

*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	13.53	0.33159
2	12	15.80	0.20060
3	12	7.24	0.84126
4	12	10.01	0.61524
5	12	9.86	0.62796
6	12	8.87	0.71378
7	12	9.19	0.68651
8	12	8.17	0.77200
9	12	25.71	0.01180
10	12	9.70	0.64199
11	12	16.93	0.15208
12	12	8.72	0.72654
13	12	11.58	0.47970
14	12	12.37	0.41659
15	12	9.49	0.66100
16	12	12.04	0.44274
17	12	7.74	0.80490
18	12	10.34	0.58581
19	12	12.86	0.37910
20	12	17.46	0.13321
21	12	8.23	0.76696
22	12	9.00	0.70287
23	12	7.10	0.85098
24	12	8.50	0.74510

25	12	10.23	0.59556
26	12	15.03	0.24002
27	12	13.30	0.34738
28	12	12.96	0.37225
29	12	7.39	0.83075
30	12	7.31	0.83618
31	12	10.41	0.58016
32	12	25.38	0.01312
33	12	12.26	0.42503
34	12	12.81	0.38290
35	12	8.48	0.74691
36	12	9.21	0.68449
37	12	17.31	0.13833
38	12	14.76	0.25456
39	12	5.25	0.94918
40	12	10.99	0.52938
41	12	9.24	0.68248
42	12	9.91	0.62415
43	12	13.02	0.36749
44	12	22.87	0.02881
45	12	15.05	0.23868
46	12	4.57	0.97074
47	12	15.01	0.24104
48	12	18.16	0.11088
49	12	20.57	0.05708
50	12	9.29	0.67821
51	12	12.07	0.44034
52	12	10.37	0.58394
53	12	11.57	0.48113
54	12	9.02	0.70111
55	12	9.16	0.68921
56	12	20.34	0.06097
57	12	7.59	0.81629
58	12	4.84	0.96315
59	12	22.04	0.03713
60	12	22.02	0.03724
61	12	6.12	0.90991
62	12	13.71	0.31956
63	12	4.33	0.97664
64	12	16.61	0.16489
65	12	18.05	0.11414
66	12	8.89	0.71247
67	12	13.58	0.32806
68	12	13.63	0.32469
69	12	9.72	0.64074
70	12	15.39	0.22076
71	12	7.90	0.79305
72	12	16.43	0.17252
73	12	11.57	0.48047
74	12	30.25	0.00256
75	12	15.37	0.22175
76	12	14.47	0.27163
77	12	4.17	0.98024
78	12	22.07	0.03671
79	12	8.69	0.72893
80	12	10.36	0.58418

81	12	21.47	0.04391
82	12	8.22	0.76771
83	12	4.81	0.96407
84	12	17.43	0.13413
85	12	12.95	0.37234
86	12	6.99	0.85827
87	12	13.75	0.31682
88	12	7.88	0.79433
89	12	7.09	0.85138
90	12	9.44	0.66479
91	12	9.47	0.66252
92	12	11.42	0.49336
93	12	11.05	0.52504
94	12	17.94	0.11757
95	12	4.55	0.97145
96	12	12.93	0.37390
97	12	6.90	0.86398
98	12	16.27	0.17912
99	12	19.30	0.08160
100	12	4.13	0.98096
Combined P-value for all tests (Using KS method)			0.69328

*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.

<b>Combination of p-values using Holm's Method</b>		
<b>Test</b>	<b>P-Value</b>	<b>P-Adjusted</b>
Opening Score (Player)	0.30313	0.99517
Opening Score (Dealer)	0.04963	0.24815
Dealer's Final Score	0.24879	0.99517
Player Cards Rank	0.90450	1.00000
Dealer Cards Rank	0.69328	1.00000
<b>Combined P-Value using Holm's Method</b>		0.24815

*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.

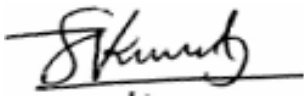
iTech Labs has done limited sanity checks to verify the integrity of the game logs. iTech Labs also maintains a copy of the game logs for verification purposes. There were a large enough number of game records to give the calculations sufficient statistical power.

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.

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**Signed:**



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**Kiren Sreekumar**  
**Principal Consultant**  
**iTech Labs Australia**  
Date: 29 June 2023

**Signed:**



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**Gyulserian Hyussein**  
**Senior Consultant**  
**iTech Labs Australia**  
Date: 29 June 2023

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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.

