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RvA Registration Number of Accreditation applicable to this Report:	
Testing	L372

Report Type	Evaluation
Report Date	16 December 2020
Issuing Laboratory	GLI Europe B.V.
Evaluating Laboratory	GLI Europe B.V.
Recipient	Virtue Gaming Operations Ltd Level 2, Quantum House 75 Abate Rigord Street Ta Xbiex, XBX 1120 Malta
Tested against Requirements	L.N. 243 of 2018 - GAMING ACT (CAP. 583) Gaming Authorisations Regulations, 2018 Directive 2 of 2018 - Player Protection Directive
Jurisdiction	Malta Online
Manufacturer	Virtue Gaming Operations Ltd Level 2, Quantum House 75 Abate Rigord Street Ta Xbiex, XBX 1120 Malta
Submitter	Virtue Gaming Operations Ltd Level 2, Quantum House 75 Abate Rigord Street Ta Xbiex, XBX 1120 Malta
Product Name	**Mental Poker 1.0.7**
Description of the Product Tested	**poker-deck.js** **deck-recovery.js** **crypto-utils.js** As requested per submitter's letter received 7 April 2020.
Evaluation Period	8 April 2020 / 9 June 2020
Internal Reference	RN-332-VGO-20-01
Result	Pass (See Comments and Conditions on the following pages)
Internal methods used reference	Random Number Generator (RNG) Analysis WI-MA-006, PC-TC-001
Revision Notice	This Revised Report replaces Report RN-332-VGO-20-01 dated 11 June 2020. This Revised Report was issued in order to: • Update the version of the RNG to 1.0.7 throughout this report; • Update the signatures of file the "poker-deck.js" on page 2 of this report.

Technical Evaluation authorized by:

Martin Britton
Managing Director

RANDOMNESS REPORT FOR THE MENTAL POKER 1.0.7 RNG

The intent of this report is to indicate that Gaming Laboratories International, LLC (GLI) has completed its evaluation of the Mental Poker random number generator (RNG), 1.0.7, provided by Virtue Gaming Operations ltd.

SECTION I — SCOPE OF TESTING

Virtue Gaming Operations ltd submitted the required materials to GLI in order to conduct a random number generator analysis on the Mental Poker 1.0.7 RNG. The scope of this analysis was limited to software verification, source code review, and data analysis. The RNG was tested for its ability to randomly produce outcomes for a virtual table of poker game.
The Mental Poker 1.0.7 RNG was evaluated against the RNG-specific requirements of the following technical standards:

- Malta Online:

  - L.N. 243 of 2018 - GAMING ACT (CAP. 583) Gaming Authorisations Regulations, 2018.
  - Directive 2 of 2018 - Player Protection Directive.

SECTION II — SOFTWARE VERIFICATION

Verify+ by Kobetron™ signatures for the Mental Poker 1.0.7 RNG are as follows:

File	Version	Type	Signature
poker-deck.js	1.0.7	Kobe4	A571
		MD5	F70845F8DC0F226DBB297F8B80E00E00
		SHA-1	1127BE47D61E15C0ACC884814D1B8206527B0B0A
		Kobe40	0012AC87C3U9PCA5661959163U749P47C7P39UF9
		CDCK	3DCF
deck-recovery.js	1.0.7	Kobe4	87H8
		MD5	AD1CAAE4DB1F6A8103B285E71ABD47B5
		SHA-1	4690534FDDF68D4CC19130FCD7FA7AD4E49883D9
		Kobe40	5302AA8AC924191A1CP6A8H4PA09041FH8P32416
		CDCK	2D2F
crypto-utils.js	1.0.7	Kobe4	U2CH
		MD5	C46676B00567E579104EADBB3D84573A
		SHA-1	984673CA31B8C05AD0B086013805D5CFF9A4E679
		Kobe40	1HUA2A6877AAF869F2AA66H77904FF27890A7737
		CDCK	CA1F

Table 1. Digital Signatures

SECTION III — SOURCE CODE REVIEW

Virtue Gaming Operations Ltd submitted appropriate documentation and FULL source code which pertains to the generation of random numbers. GLI reviewed the source code provided by tracing the path of the RNG application from the initiation of the draw to the selected output of random numbers. GLI inspected the source code, where practicable, in an attempt to find any undisclosed switches or parameters having a possible influence on randomness and fair play. GLI assessed the ability of the RNG to produce all numbers within the desired range.

SECTION IV — DATA ANALYSIS

The game configuration and parameters for the data obtained and tested are listed in Table 2. GLI performed a data format check on each data set listed in order to confirm that the game parameters were correctly represented in the data analyzed.
A set of numbers is said to be drawn without replacement if a number can only be selected once within the same draw.

Data Set	Range	Positions	Replacement	Draws
poker	0-51	52	No	5,000,000

Table 1. Game Parameters

For a summary of the statistical tests applied to each data set, see Appendix A. For a description of the overall test methodology and a description of each test used, see Appendix B.
Overall, the RNG passed the battery of tests for each configuration at the 95%, 98%, and 99% confidence levels.

SECTION V — SUMMARY

Overall Evaluation of the Random Number Generator

GLI's conclusion based upon the tests applied to the Mental Poker 1.0.7 RNG data is that this random number generator has exhibited random behavior and is suitable for the applications as described herein. If a game utilizes a different range or a different number of selections from the included ranges, the RNG should be resubmitted to test that set of parameters.

APPENDIX A: Statistical Test Summary

Data Set	Range	Positions	Replacement	Draws	Runs	Serial Corr.	Interplay Corr.	Adj. Max-Min	Adj. High-Low	Adj. Blocks	Coupon	Duplicates	Overlaps	Permutation	Tot. Dist.	Tot. Dist. by Pos.
poker	0-51	52	No	5,000,000	X	X	X	X	X	X	X	X	X	X	X	X

Table A 1 Tests Applied

APPENDIX B: Test Descriptions

B.1 Definitions. The following terms apply to the below test descriptions. Randomness Device or Random Number Generator (RNG) output may be collected multiple numbers at a time. Each set of numbers is called a draw. Each individual number has a particular order within the draw. This is referred to as the number position.

B.2 Distribution Comparisons. Many of the tests compare an observed numerical distribution with an expected distribution. Unless otherwise specified, this is done by means of a statistical chi-square goodness-of-fit test. The value chi-square is computed in the standard way. If *k* is a possible value, o_k is the observed count of that value, and e_k is the expected count:

$$\chi^2 = \sum_k \frac{(o_k - e_k)^2}{e_k}$$

In the case where expected counts are too small for accurate use of the above formula, values are 'binned' together to ensure an appropriate minimum expected count. The resultant value for chi-square is compared against the distribution for the appropriate number of degrees of freedom. Unusually high (distribution mismatch) or unusually low (insufficient randomness) chi-square values can be causes for data failure.

B.3 Meta-testing. Evaluation of groups of *p*-values may include a meta-test for extremity of high or low *p*-values, a meta-test for frequency of high or low *p*-values, and a meta-test for uniformity of *p*-values, as appropriate.

B.4 Confidence Level. The statistical tests conducted by GLI are done at a particular *confidence level*. Common confidence levels used include 95%, 98%, and 99%, depending on jurisdictional requirements, and intended use of the RNG. High confidence level testing has low risk of mistakenly failing a good RNG, but higher risk of passing a bad RNG. Lower confidence level testing has increased power of detecting bad RNGs, while also increasing the risk of false failures of good RNGs. Specifically, the confidence level represents the probability that an ideal source of randomness would pass the testing. If an RNG passes statistical tests at a given confidence level, passage at all *higher* confidence levels is implied.

B.5 Tests. Some tests are only applicable to certain types of data. Some tests may be applied only to a portion of the data. Some tests may require that the data be parsed, binned, or otherwise transformed, as necessitated by data format.

Adjacency Blocks:

For each draw, the data is first sorted. Then the amount of contiguous blocks of numbers is counted. These statistics are then compared against the expected. For example, if a draw consists of the numbers:

$$1, 5, 4, 2, 6, 9$$

the data would be sorted and separated into blocks. The resulting statistic would be 3.

Adjacency High-Low:

For each draw, the number of local extrema ('highs' and 'lows') in the data is recorded and compared with the expected distribution. These are also referred to as 'turning points'. For example, if a draw consists of the numbers:

$$1, 3, 5, 7, 2, 9$$

there would be one local maximum (7) and one local minimum (2). The resulting statistic would be 2.

Adjacency Max-Min:

For each draw, the difference between the maximum and minimum values is calculated and recorded. This is compared with the expected theoretical distribution. For example, if a draw consists of the numbers:

$$2, 3, 6, 7, 4$$

the resulting statistic would be 5, the difference between the maximum value (7) and the minimum value (2).

APPENDIX B: Test Descriptions

Coupon Collector's:

The Coupon Collector's Test is applied positionally. The data is parsed until all possible values have been observed, then the number of values checked is recorded and the count is restarted. This is compared with the expected distribution. For example, if the set of all possible values is {0, 1, 2} and the first position of each draw is:

$$1, 0, 1, 0, 2, 0, 1, 2, \ldots$$

then all values are observed in the first position by the fifth draw. All values are then observed within the next 3 draws, so the first two statistics for the first position would be 5 and 3.

Duplicates:

The Duplicates Test counts the number of times a draw is exactly duplicated in the data. In the case that a particular draw is repeated more than twice, every possible way to generate a duplicate is counted. This is compared against the theoretical distribution to verify that the number of duplicate draws falls within expected bounds. For example, consider the dataset consisting of the following draws of two numbers each.

$$\begin{array}{l} a)\ 1, 3 \\ b)\ 4, 1 \\ c)\ 1, 3 \\ d)\ 1, 3 \\ e)\ 4, 1 \\ f)\ 3, 1 \end{array}$$

The duplicate pairs are (*a,c*), (*a, d*), (*c, d*), and (*b, e*), for a total of 4 duplicates. *(f)* is not counted as a duplicate since the draw must match in order as well as values.

Interplay Correlation:

The Interplay Correlation Test measures statistical correlation between different positions of the same draw. For each pair of positions, statistical correlation is calculated as in the Serial Correlation Test. In the case of without replacement data, an adjustment is made to account for the expected resulting negative correlation.

Overlaps:

The Overlaps Test compares consecutive draws for overlapping values. The number of overlapping values is recorded for each pair of draws. This observed distribution of overlaps is then compared against the expected distribution. For example, if the following draws are observed consecutively,

$$\begin{array}{l} a)\ 1, 4, 5, 6 \\ b)\ 4, 1, 7, 6 \end{array}$$

the number of overlaps would be 3, representing the values 1, 4, and 6.

APPENDIX B: Test Descriptions

Permutation:

The Permutation Test is a test applicable to data that represents a reordering of numbers. Each draw can be considered as a permutation of the original ordering. Every permutation can be decomposed into disjoint cycles, which represent the possible positions a number would occupy if the same permutation is applied repeatedly. For each draw, three statistics are collected based on the cycle decomposition:

- The number of cycles.
- The size of the smallest cycle.
- The size of the largest cycle.

Each of these statistics generates a distribution of observations which are compared with their respective expected distributions. For example, if the following draw were observed as a reordering of the numbers from 1 to 6,

$$1, 3, 5, 4, 2, 6$$

the cyclic decomposition would be (1)(2 3 5)(4)(6). 1, 4, and 6 remain in their original positions, so they form their own cycles. The values 2, 3, and 5 are shuffled, so they form a single cycle together. The total number of cycles is 4, the smallest cycle has size 1, and the largest cycle has size 3.

Runs:

The Wald-Wolfowitz Runs Test is applied to each position within the draw. A center is established, typically the data median, and the number of 'runs' above and below the center are tallied. Values exactly equal to the center are discarded. This is compared to the expected distribution, which depends on the number of values above and below the center. For example, if the numbers drawn at a particular position were:

$$2, 3, 1, 5, 4, 7, 3, 2, 3, 2, 3, 2, 6, 7, 3, 5$$

and the established center were the data median of 3, the data would be parsed for runs above 3 and runs below 3.

$$\underbrace{2, 3, 1}, \overbrace{5, 4, 7, 3}, \underbrace{2, 3, 2, 3, 2}, \overbrace{6, 7, 3, 5}$$

This would be counted as 4 runs.

Serial Correlation:

The Serial Correlation Test measures statistical correlation between consecutive draws of the same position. For each position, the sample Pearson correlation coefficient is calculated. If *X* represents the first number, and *Y* the number that follows, then the coefficient is:

$$r = \frac{cov(X, Y)}{s_X s_Y}$$

where *s* denotes the sample standard deviation. The coefficients are used to generate a *p*-value for each position.

Total Distribution:

The Total Distribution Test is a simple tally of all observed values throughout the data. This is compared with the expected distribution. Typically the expected distribution is a uniform distribution. In the case of unequal weighting of values, an appropriate discrete distribution is used.

Total Distribution by Position:

The Total Distribution by Position Test tallies the observed distribution of values for each position within the draw. Each of these distributions is then compared with the expected.

Jurisdictional Requirements

GLI's evaluation to the Technical Standard was limited only to the requirements applicable to the Mental Poker 1.0.7. In addition, the following sections of the applicable Technical Standard were excluded from the scope of work for this evaluation:

Technical Standard Section(s)	Reason for Exclusion
All, except requirements directly referring to Random Numbers Generators.	RNG Evaluation only