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USE OF BOTH SUM OF RANKS AND DIRECT HITS IN FREE-RESPONSE PSI EXPERIMENTS

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ABSTRACT: Free-response ESP experiments have used a number of different statistical indices for evaluation. Although reseachers have been criticized for using multiple indices without appropriate adjustments, there are good reasons for using several different indices. Some of these reasons are described herein.

This report discusses the use of both the sum of ranks and the direct hit measures. A procedure correcting for the dual analysis is described. This method, however, solves only one of the potential problems that may arise with multiple analysis. A BASIC computer program implementing this procedure is presented, and a table given for experiments that have four items in a target pool and sample sizes of 10, 20, 30, and 40 trials.

A number of methods have been developed to statistically evaluate free-response ESP experiments. Burdick and Kelly (1977) have described two general approaches, atomistic and wholistic. Atomistic methods evaluate discrete portions of a response generated by a subject attempting to use ESP. Some recent procedures have been presented by Honorton (1975), Jahn, Dunne, and Jahn (1980), and May, Humphrey, and Mathews (1985). A wholistic approach involves comparing a subject's total response with members of the judging pool (the actual target and some number of decoys). The items in the pool are given rankings or ratings to indicate the level of correspondence with the subject's response. This might be done by the subject or by an outside judge who is blind to the correct match.

Wholistic approaches include the sum-of-ranks statistic (Solfvin, Kelly, & Burdick, 1978), direct hits, binary hits, and standardized ratings (Stanford & Mayer, 1974). In the psi ganzfeld work, the direct-hits measure has been the statistic most frequently used, but the sum-of-ranks method has also seen wide acceptance (Honorton, 1985).

WHICH IS THE BEST STATISTIC?

The best statistic is a matter of some question, and a number of investigators have commented on the effectiveness of various measures. Stanford and Sargent (1983) have described the standardized ratings as being "particularly psi-sensitive" (p. 319). Sargent (1980) has called the binary hit measure "very insensitive" (p. 7).

It should be kept in mind that the actual power of a test will depend on how psi occurs and on how the judging is done. There are a number of ways ESP could manifest. For instance, perhaps it is an "all-or-none" phenomenon. In that case, a subject would either get a direct hit or not; and, if not, his attempt would not be any more likely to get a second place rank than it would a fourth place. Perhaps psi operates so that a first place ranking is more likely than a second place, and a second place is more likely than a third place, and so on. Perhaps the effect operates so that the target is simply more likely to be placed in the top half of the rankings than in the bottom half.

If psi operates so that there are mostly low-valued ranks in an experiment, then the sum-of-ranks statistic would be the best to use. But if psi operates in an all-or-none fashion (an extrachance number of first place ranks but all other rankings evenly distributed), then the direct-hits measure is more powerful. Before any valid statement can be made about power comparisons of various statistical analyses, the assumed mode in which psi occurs must be specified. McConnell (1958) pointed this out in a similar situation. (Although it is beyond the scope of this paper, such power comparisons can be studied with the use of simulation, which is now feasible because of the widespread availability of microcomputers [e.g., Hansen, 1986].)

It is unclear just how ESP should be expected to manifest in free-response situations. In fact, it may depend on a variety of factors. For instance, Honorton and Schechter (1986) presented data from ganzfeld research indicating that personality type is one factor that affects how psi scoring is distributed. Another factor that may influence the outcome is the target pool itself. If several items within a pool are somewhat similar, a judge may experience some confusion; as a result, a target may receive a second place rank rather than a first place rank. For instance, if several pictures of people are included in the pool and the subject's response mentions people, the judge may have some difficulty. In such situations, the sum-of-ranks index may be more powerful than the direct-hits index. If a judge is inexperienced, he or she may pay attention only to the best match and neglect the others. In such cases, a second place target rank may be no more likely than a last place ranking; in this instance, the direct-hits measure would be more sensitive than the sum of ranks.

Reasons for Several Measures

There are a number of reasons an investigator might wish to use several indices to check for statistical significance. As just mentioned, psi may manifest in several ways; a researcher may want to allow for several possibilities. Another reason one may desire to use multiple indices is that discrete distributions can impose a more severe requirement than intended. As an example, in Table A.1 published by Solfvin, Kelly, and Burdick (1978), with $N = 10$ and $R = 4$, a sum of ranks of 18 or less corresponds to a probability of .033; the next highest sum (19) corresponds to a probability of .06. In such circumstances, a second appropriate criterion can be allowed for significance testing while keeping the significance level at or below .05.

When similar cases arose previously, the Bonferroni method (e.g., Rosenthal & Rubin, 1984) could be used to correct for multiple analysis (e.g., Honorton, 1985). This procedure is conservative because its p values are derived from an extreme negative association between the measures. For many cases, this is unrealistic. In a typical ganzfeld experiment, for instance, a large number of direct hits would be associated with a small sum of ranks; Hyman (1985) found these to be highly correlated.

Use of Both Direct Hits and Sum of Ranks

In the following text, we present a method enabling the use of both direct hits and sum of ranks together to test for statistical significance but avoiding the excess conservatism (and loss of statistical power) associated with the Bonferroni method. A computer program was written to calculate exact bivariate probabilities assuming that both the direct-hits and sum-of-ranks indices were checked. The appendixes contain a description of the calculation procedure and rationale, an annotated computer program in Applesoft™ BASIC, and a table that gives examples.

Table 1 in Appendix A gives results of calculations for experiments with 10, 20, 30, and 40 trials, each with four items in a target pool (and therefore a probability of a direct hit of .25). To save space, we show only limited regions of the distributions. It should be noted that the computer program can handle many more cases than the four examples.

There are two ways to use the table. The "p-value" approach is to observe the data first, then read the combined level of significance from the table. For example, in a 10-trial experiment with four items in a judging pool, observing six direct hits and a sum of ranks of 16 would give a p value of .02137. This means that the probability of observing six or more direct hits, or a sum of ranks of 16 or less, or both, is .02137 under the null hypothesis.

The second approach to using the table is to decide in advance which pairs will constitute a significant result. This approach has the advantage of allowing the experimenter to place more emphasis on one of the measures over the other.

Suppose that you wish to conduct a 20-trial experiment with direct hits as the primary analysis. The cumulative binomial distribution (from a table or calculation) indicates that nine direct hits are needed (for a probability of .04093). Eight direct hits gives an associated probability of .10181. Consulting part B of Table 1 in Appendix A indicates that a second criterion can be allowed (i.e., a sum of ranks of 39 or less). This gives an overall probability value of .04611. Thus, if the experiment resulted in only six direct hits but a sum of ranks of 39, it would still be significant because one of the prespecified criteria was met.

As another example, suppose that you wish to conduct a 30-trial experiment and to weigh each criterion approximately equally. In that case, you might specify the criteria of either 13 or more direct hits or a sum of ranks of 63 or less for an overall probability of .03946. Individually, the probability of 13 (or more) direct hits is .02159, and that of a sum of ranks of 63 (or less) is .02992. If the Bonferroni method was used, the conservative p value would be .02159 + .02992 instead of the exact p = .03946.

One word of caution must be inserted here. One must decide in advance whether only direct hits or sums of ranks will be used, or both. It is not legitimate to use the best of the p values resulting from each of the two separate measures and the combined measure. These methods also require trials that can properly be considered independent (see Kennedy, 1979, for discussion).

Appendix A

Calculation Procedure and Rationale

The calculation for exact bivariate probabilities is made by considering a multinomial distribution where all possible outcomes of a trial are equiprobable (i.e., a target is equally likely to be assigned any of R ranks). Nearly all elementary books on probability discuss this (e.g., Harris, 1966). For N trials, there are R^N possible assignments of the ranks. The maximum sum obtainable would be $N \cdot R$ (all complete misses); the minimum sum would be N (all direct hits).

Let n_k designate the number of targets given a kth rank, n_k being a nonnegative integer.

$$N = n_1 + n_2 + \dots n_R \qquad (1)$$

The two statistics of interest are the sum of ranks (M), given by

$$M = 1 \cdot n_1 + 2 \cdot n_2 + \dots + R \cdot n_R,$$

and

$$D = \text{number of direct hits} = n_1.$$

Notice that these are both functions of $(n_1, n_2, \dots, n_R)$. Therefore, the combined probability associated with particular values of the pair (D, M) is the sum of the probabilities of all sets of $(n_1, n_2, \dots, n_R)$ for which those particular values are obtained.

It follows that to compute those probabilities, we need to enumerate the probabilities for all sets $(n_1, n_2, \dots, n_R)$ that satisfy Equation 1. Then, as we enumerate each set, we compute (D, M) and accumulate the probability for that pair.

As a small example, suppose that $N = 2$ and $R = 2$. Then $n_1 + n_2 = 2$. The possible sets of (n_1, n_2), their probabilities (under the null hypothesis), and the associated (D, M) are:

(n_1, n_2)	Probability	(D, M)
(0, 2)	¼	(0, 4)
(1, 1)	½	(1, 3)
(2, 0)	¼	(2, 2)

In this case there is only one set of (n_1, n_2) corresponding to each (D, M) pair. In general, for each (D, M) pair we would add the probabilities of all sets of n_K's resulting in that pair.

The remaining question is how to enumerate and compute probabilities for the sets $(n_1, n_2, \dots, n_R)$. Under the null hypothesis, each trial is equally likely to receive any of the R ranks, so the set $(n_1, \dots, n_R)$ has a multinomial distribution with equal probabilities, each $1/R$. Thus,

$$P(n_1, n_2, \dots, n_R) = \frac{N!}{n_1!\, n_2! \dots n_R!} \left(\frac{1}{R}\right)^N \qquad (2)$$

The challenge in writing the program was to find a way to systematically

Table 1

Exact Probability of Obtaining Either the Indicated Number of Direct Hits (or More) or the Indicated Sum of Ranks (or Less) or Both

A. For 10-trial experiment with p (hit) = .25

	Sums of ranks							
Direct hits	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*
0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1	.94369	.94369	.94369	.94369	.94369	.94369	.94369	.94369
2	.75597	.75597	.75597	.75597	.75597	.75597	.75597	.75597
3	.47441	.47441	.47441	.47441	.47441	.47441	.47441	.47441
4	.22412	.22412	.22412	.22412	.22412	.22412	.22412	.22424
5	.07813	.07813	.07813	.07813	.07813	.07813	.07833	.07964
6	.01973	.01973	.01973	.01973	.01973	.01997	.02137	.02629
7	.00351	.00351	.00351	.00351	.00371	.00475	.00815	.01628
8	.0004	.0004	.0004	.0005	.00107	.00280	.00701	.01582
9	.00003	.00003	.00007	.0002	.0009	.00276	.00701	.01582
10	.00000	.00001	.00006	.0002	.0009	.00276	.00701	.01582
	18	*19*	*20*	*21*	*22*	*23*	*24*	*25*
0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1	.94369	.94369	.94369	.9437	.94375	.94395	.94454	.94592
2	.75597	.75598	.75607	.75651	.75805	.7622	.7712	.7874
3	.47445	.4748	.47643	.48168	.49464	.52041	.56306	.62286
4	.22508	.22864	.23908	.26275	.30615	.37278	.4604	.56107
5	.08469	.09826	.12673	.17564	.24727	.33914	.44478	.55546
6	.03855	.06294	.10366	.16338	.24222	.3377	.44454	.55546
7	.03234	.05993	.10266	.16318	.24222	.3377	.44454	.55546
8	.03223	.05993	.10266	.16318	.24222	.3377	.44454	.55546
9	.03223	.05993	.10266	.16318	.24222	.3377	.44454	.55546
10	.03223	.05993	.10266	.16318	.24222	.3377	.44454	.55546

Table 1A continued

	Sums of ranks							
Direct hits	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*
0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1	.94864	.95316	.95961	.96757	.97611	.98408	.99053	.99505
2	.81209	.84434	.88072	.91641	.94692	.9697	.98457	.99304
3	.69506	.77091	.84094	.89826	.94018	.96777	.98418	.99299
4	.6637	.75798	.83682	.89734	.94007	.96777	.98418	.99299
5	.6623	.75778	.83682	.89734	.94007	.96777	.98418	.99299
6	.6623	.75778	.83682	.89734	.94007	.96777	.98418	.99299
7	.6623	.75778	.83682	.89734	.94007	.96777	.98418	.99299
8	.6623	.75778	.83682	.89734	.94007	.96777	.98418	.99299
9	.6623	.75778	.83682	.89734	.94007	.96777	.98418	.99299
10	.6623	.75778	.83682	.89734	.94007	.96777	.98418	.99299
	34	*35*	*36*	*37*	*38*	*39*	*40*	
0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	
1	.99777	.99915	.99974	.99994	.99999	1.00000	1.00000	
2	.99724	.99905	.99973	.99994	.99999	1.00000	1.00000	
3	.99724	.99905	.99973	.99994	.99999	1.00000	1.00000	
4	.99724	.99905	.99973	.99994	.99999	1.00000	1.00000	
5	.99724	.99905	.99973	.99994	.99999	1.00000	1.00000	
6	.99724	.99905	.99973	.99994	.99999	1.00000	1.00000	
7	.99724	.99905	.99973	.99994	.99999	1.00000	1.00000	
8	.99724	.99905	.99973	.99994	.99999	1.00000	1.00000	
9	.99724	.99905	.99973	.99994	.99999	1.00000	1.00000	
10	.99724	.99905	.99973	.99994	.99999	1.00000	1.00000	

B. For 20-trial experiment with p(hit) = .25

	Sums of ranks							
Direct hits	*36*	*37*	*38*	*39*	*40*	*41*	*42*	*43*
0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1	.99683	.99683	.99683	.99683	.99683	.99683	.99683	.99683
2	.97569	.97569	.97569	.97569	.97569	.97569	.97569	.97569
3	.90874	.90874	.90874	.90874	.90874	.90874	.90874	.90874
4	.77484	.77484	.77484	.77484	.77485	.77485	.77487	.77493
5	.58516	.58516	.58516	.58516	.58518	.58524	.58545	.586
6	.38283	.38283	.38284	.38288	.38304	.38351	.38472	.3875
7	.21422	.21424	.21433	.21462	.21546	.21753	.22203	.23074
8	.10185	.10199	.10243	.10362	.10642	.1122	.12289	.14075
9	.04116	.04169	.04305	.04611	.05214	.06288	.08025	.10608
10	.01463	.01592	.01866	.02391	.03298	.04739	.06867	.09818
11	.00558	.00766	.01155	.01819	.02877	.04459	.06701	.09731
12	.00340	.00592	.01028	.01737	.0283	.04435	.06691	.09728
13	.00308	.00572	.01018	.01732	.02828	.04435	.06691	.09728
14	.00307	.00572	.01017	.01732	.02828	.04435	.06691	.09728
15	.00307	.00572	.01017	.01732	.02828	.04435	.06691	.09728
16	.00307	.00572	.01017	.01732	.02828	.04435	.06691	.09728
17	.00307	.00572	.01017	.01732	.02828	.04435	.06691	.09728
18	.00307	.00572	.01017	.01732	.02828	.04435	.06691	.09728
19	.00307	.00572	.01017	.01732	.02828	.04435	.06691	.09728
20	.00307	.00572	.01017	.01732	.02828	.04435	.06691	.09728

C. For 30-trial experiment with p(hit) = .25

	Sums of ranks							
Direct hits	*62*	*63*	*64*	*65*	*66*	*67*	*68*	*69*
0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1	.99982	.99982	.99982	.99982	.99982	.99982	.99982	.99982
2	.99804	.99804	.99804	.99804	.99804	.99804	.99804	.99804
3	.9894	.9894	.9894	.9894	.9894	.9894	.9894	.9894
4	.96255	.96255	.96255	.96255	.96255	.96255	.96255	.96256
5	.90213	.90213	.90213	.90213	.90213	.90214	.90216	.9022
6	.7974	.7974	.79741	.79742	.79744	.79751	.79765	.79796
7	.65195	.65196	.65199	.65206	.65224	.65262	.65339	.65486
8	.48575	.48581	.48598	.48636	.48718	.48877	.49167	.49662
9	.32661	.32693	.32763	.32906	.33177	.33653	.34438	.3565
10	.19745	.19853	.20066	.20454	.21114	.22165	.23737	.25954
11	.10834	.11103	.11577	.1236	.1357	.15331	.17754	.20919
12	.05662	.06165	.06971	.08188	.09922	.12271	.15306	.19059
13	.03212	.03946	.05034	.06569	.08635	.11302	.14619	.18603
14	.02312	.03196	.04442	.06127	.08326	.11101	.14497	.18535
15	.02073	.0302	.04321	.0605	.0828	.11076	.14485	.18529
16	.02031	.02994	.04306	.06042	.08277	.11074	.14484	.18529
17	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529
18	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529
19	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529
20	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529
21	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529
22	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529
23	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529
24	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529

Table 1C continued

Direct hits	*62*	*63*	*64*	*65*	*66*	*67*	*68*	*69*
25	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529
26	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529
27	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529
28	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529
29	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529
30	.02027	.02992	.04305	.06042	.08276	.11074	.14484	.18529

D. For 40-trial experiment with p (hit) = .25

	Sums of ranks							
Direct hits	*83*	*84*	*85*	*86*	*87*	*88*	*89*	*90*
0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1	.99999	.99999	.99999	.99999	.99999	.99999	.99999	.99999
2	.99986	.99986	.99986	.99986	.99986	.99986	.99986	.99986
3	.99898	.99898	.99898	.99898	.99898	.99898	.99898	.99898
4	.9953	.9953	.9953	.9953	.9953	.9953	.9953	.9953
5	.98396	.98396	.98396	.98396	.98396	.98396	.98396	.98396
6	.95673	.95673	.95673	.95673	.95673	.95673	.95673	.95673
7	.90378	.90378	.90378	.90378	.90378	.90378	.90378	.90378
8	.81805	.81805	.81805	.81805	.81805	.81805	.81806	.81808
9	.70017	.70017	.70017	.70017	.70019	.70021	.70027	.70038
10	.56046	.56047	.56048	.5605	.56056	.56068	.56094	.56142
11	.41611	.41613	.41618	.41629	.41653	.417	.41787	.41942
12	.28492	.28501	.2852	.28559	.28634	.28771	.29006	.29392
13	.17937	.17966	.18023	.18129	.18317	.18631	.19133	.19895
14	.10394	.10467	.106	.10828	.11202	.11782	.12643	.13864

Table 1D continued

Direct hits	*83*	*84*	*85*	*86*	*87*	*88*	*89*	*90*
15	.05612	.0576	.06008	.06405	.07007	.07884	.09105	.10741
16	.0295	.03192	.03572	.04139	.04952	.06072	.07559	.09468
17	.01673	.02005	.02495	.03191	.04145	.0541	.07038	.09076
18	.01164	.01557	.02115	.02881	.03902	.05229	.06909	.08989
19	.01001	.01425	.02012	.02805	.03849	.05193	.06887	.08976
20	.00962	.01396	.01992	.02792	.03841	.05189	.06884	.08975
21	.00955	.01392	.0199	.0279	.0384	.05188	.06884	.08975
22	.00955	.01392	.01989	.0279	.0384	.05188	.06884	.08975
23	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
24	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
25	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
26	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
27	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
28	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
29	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
30	.00954	.01392	.01989	.0279	.0383	.05188	.06884	.08975
31	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
32	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
33	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
34	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
35	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
36	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
37	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
38	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
39	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975
40	.00954	.01392	.01989	.0279	.0384	.05188	.06884	.08975

enumerate all possible sets of n_k's. Notice that an arrangement can be specified by writing down $N + R - 1$ "slots" and placing "pegs" in $R - 1$ of them. The number of slots before the first peg is n_1, between the first and second peg is n_2, and so forth. For example, if $N = 2$ and $R = 2$, we would have three slots and one peg, resulting in:

$$\underline{1}\ \underline{\quad}\ \underline{\quad}\ ,\text{ or }\ \underline{\quad}\ \underline{1}\ \underline{\quad}\ ,\text{ or }\ \underline{\quad}\ \underline{\quad}\ \underline{1}$$

corresponding to (n_1, n_2) of (0, 2), (1, 1), and (2, 0), respectively.

Using this concept, the program systematically moves the pegs until all sets of n_k have been enumerated. The number of sets is:

$$C^{N+R-1}_{R-1} = \frac{(N + R - 1)!}{N!\,(R-1)!}$$

For each set, D and M are calculated, and the probability given by Equation 2 is added to the appropriate cell in Table 1.

Appendix B

Annotated Computer and Program in Applesoft BASIC

```
  10   REM Program calculates probabilities for using both direct
  20   REM hits and sum of ranks

  70   INPUT "NUMBER OF TRIALS>"; T
  80   INPUT "NUMBER OF RANKS>"; R
  85   REM Maximum R = 8
  90   REM Maximum T depends on R and computer memory
 100   DIM D (T,R * T)
 200   X = T: GOSUB 6000: TFAC = FAC

 410   FOR P1 = 1 TO T + 1
 412   IF R = 2 THEN GOSUB 2000: NEXT : GOTO 600
 420   FOR P2 = P1 + 1 TO T + 2
 422   IF R = 3 THEN GOSUB 2000: NEXT : GOTO 560
 430   FOR P3 = P2 + 1 TO T + 3
 432   IF R = 4 THEN GOSUB 2000: NEXT : GOTO 550
 440   FOR P4 = P3 + 1 TO T + 4
 442   IF R = 5 THEN GOSUB 2000: NEXT : GOTO 540
 450   FOR P5 = P4 + 1 TO T + 5
 452   IF R = 6 THEN GOSUB 2000: NEXT : GOTO 530
 460   FOR P6 = P5 + 1 TO T + 6
 462   IF R = 7 THEN GOSUB 2000: NEXT : GOTO 520
```



```
 470   FOR P7 = P6 + 1 TO T + 7
 472   IF R = 8 THEN GOSUB 2000: NEXT
 510   NEXT P6
 520   NEXT P5
 530   NEXT P4
 540   NEXT P3
 550   NEXT P2
 560   NEXT P1

 600   TT = R ∧ T
 698   REM This section cumulates counts in each cell to
 699   REM determine the cumulative distribution
 700   FOR I = T TO T * R
 710    FOR J = 0 TO T
 720     IF J = 0 THEN V = 0: GOTO 850
 730     IF I = R * T THEN V = 0: GOTO 850
 740     V = 0
 800     FOR II = I + 1 TO R * T
 810      FOR JJ = 0 TO J - 1
 820       V = V + D (JJ,II)
 830      NEXT JJ
 840     NEXT II
 850     D (J, I) = (TT - V) / TT
 860    NEXT J
 870   NEXT I

 890   REM This section prints results
 900   FOR J = T TO R * T
 910    FOR I = 0 TO T
 920     PRINT D (I,J);"      ";
 930    NEXT I
 940    PRINT
 950   NEXT J
1000   END

2000   REM
2050   P(1) = P1:P(2) = P2:P(3) = P3:P(4) = P4:P(5) = P5:
       P(6) = P6: P(7) = P7
2100   P(R) = T + R
2199   REM This loop determines 'spaces' between 'pegs'
2200   FOR I = 1 TO R
2210    X (I) = P(I) - P(I - 1) - 1
2220    X = X (I)
2230    GOSUB 6000
2240    F (I) = FAC
```

```
2250    NEXT I
2300    S = 0: TS = TFAC
2318    REM This loop calculates number of arrangements
2319    REM (N!/(n1! n2! ... nR!)
2320    FOR I = 1 TO R
2330     S = S + I * X(I)
2340     TS = TS - F(I)
2350    NEXT I
2380    D (X (1), S) = D (X (1), S) + 2.718281828 ^ TS
2400    RETURN

6000    REM Factorial, Logarithms are used
6010    IF X = 0 THEN FAC = 0: RETURN
6020    IF X = 1 THEN FAC = 0: RETURN
6050    FAC = 0
6060    FOR K = 1 TO X
6070    FAC = FAC + LOG (K)
6080    NEXT K
6100    RETURN

9000    REM For T = 10 and R = 4, estimated running time is
9001    REM approx. 7.5 minutes on an Apple
9010    REM For T = 40 and R = 4, estimated running time is
9011    REM approx. 21 hours on an Apple
```

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