Software Announcements

MSDA_2: Updated Version of Software for Multidimensional Signal Detection Analyses

Multidimensional signal detection analyses (MSDA; Kadlec, 1995) is a software program written for analyzing accuracy data, in the form of square confusion matrices, for perceptual separability (PS), decisional separability (DS), and perceptual independence (PI) of stimulus or perceptual dimensions. This announcement is an update on the original package, and readers interested in or wishing to use the MSDA software should consult the Kadlec (1995) paper for information on what the software does and how to use it.

The new version of MSDA, MSDA_2, has a number of significant improvements. The two major changes are in (1) the procedures for estimating the signal detection parameters, d' , β , and now, also, C (decision criterion), and (2) the statistical inference tests of the equivalence of these estimates that are used to assess PS, DS, and PI. The new version also provides some additional summary information not printed previously and corrects two minor errors in the z test that is used for testing the equivalence of two probability estimates (in testing for marginal response invariance and sampling independence). The remainder of this announcement addresses these changes in more detail.

Inferential tests for d' s and β s. The nonparametric inferential procedures for testing the equivalence of d' s and β s suggested by Grier (1971) are replaced by the inferential test suggested by Marascuilo (1970). For testing two d' values, the test is a two-sample z test. More generally for k ($k \geq 3$) d' s, it is a chi-square test with $k-1$ degrees of freedom. Both versions use an estimate of the standard error of the estimate from the asymptotic variance computed with:

$$\text{Var}(\hat{d}') = \frac{F(C)[1-F(C)]}{N_n f^2(C)} + \frac{F(C-d')[1-F(C-d')]}{N_s f^2(C-d')},$$

where N_n and N_s are the number of times the noise (level 1) and the signal (level 2) stimuli, respectively, were presented to the observer; C is the decision criterion point equal to the z value corresponding to the false alarm probability; d' is the sensitivity estimate estimated by z of the false alarm probability minus the z of the hit probability; $F(z)$ is the cumulative probability from negative infinity to z in a standard normal distribution, and F^{-1} is its inverse function (see next section); and $f(z)$ is the standard normal density. Note that $F(C)$ is equal to the probability of false alarm, and $F(C-d')$ is the probability of a hit.

This standard error was recently found to be very close to the expected values computed by Miller (1996) for the unbiased cases and to Monte Carlo estimates generated by Kadlec (in press).

Signal detection theory estimates. The second major change is in the estimation of the signal detection theory (SDT) parameters. Estimation has been improved by using an algorithm for computing the inverse Gaussian function, $z = F^{-1}(p)$, rather than the table look-up procedure of the first version. This algorithm, by Odeh and Evans (1974), computes the z value for a given probability assuming a standard normal cumulative distribution, and Brophy (1985) found it to be the most accurate (to 20 decimal places) of the available algorithms.

The MSDA_2 now also reports the decision criteria, C or crit, in addition to the likelihood ratios, β , with C being defined as the distance, measured from the mean of the noise distribution, to the decision criterion point. Both marginal and conditional C values are reported and are used to test for DS for each dimension across levels of the second dimension. The inferential test for the C s is analogous to Marascuilo's (1970) test for d' s. This change was made for two reasons. First, the standard error of the C estimate is easily and accurately estimated with the first term on the right-hand side of the $\text{Var}(\hat{d}')$ equation given above, whereas estimation of the standard error of the β estimate is much more complicated (Kadlec, in press). Second, testing the C values is more in line with the definition of DS and is thus a more direct test of DS. Moreover, testing C s is independent of the magnitudes of the d' estimates (and, hence, PS), whereas equality of β s across levels depends on both C and d' values and is, thus, only indirectly related to DS.

Corrections. Two minor errors were detected in the first version, both being in the z test for two probabilities (in procedure "test_p1_and_p2_for_equivalence" in unit <testUtil>). First, the denominator has been changed from $\sqrt{(\sigma_p^2)}$ to $\sigma_{p1-p2} = \sqrt{(\sigma_{p1}^2 + \sigma_{p2}^2)}$, to be more consistent with statistical theory. As before, each $\sigma_{p_i} = \sqrt{[p_i(1-p_i)/N_i]}$.

Second, the absolute value of the resulting z is now checked for significance. The first version only compared the observed z value with a positive critical z value, making this effectively a one-tailed test, rather than the desired (and claimed) two-tailed test.

Other changes. The following is a list of minor changes in Version 2, motivated by usage in our laboratory and deemed helpful, informative, and/or less annoying.

1. The number of trials per stimulus (N_i) in the confusion matrix is now reported, primarily for information and cross-checking purposes.

2. In the "Select CONFUSION MATRIX" option in the main menu (Option 2), three changes were made: (1) The user can now supply any input file name (not just a file with *.mtx extension); note, however, that the file must be in the same directory as the MSDA_2.EXE program; (2) no output file is created if no mtx file is selected; and (3) the annoying "Is this OK?" prompt is deleted.

3. In writing the output file to the screen, line length was increased from 72 to 78 characters, the full-screen width when running in 640 × 480 mode. Note that the actual output file may have lines as long as 124 characters, when a 16 × 16 confusion matrix is being analyzed.

Some cautions. In interpreting the results, the user should be aware of some potential shortcomings of the program, noted below. As with any data analysis and statistical test, the results provided by this set of procedures unfortunately are not perfect and must be supplemented with common sense. In resolving ambiguities, the general rule of thumb is to consider the entire pattern of results and weave the most coherent picture consistent with the entire set of results.

Marginal analyses. The significance test for the decision criteria (crit) should result in the same conclusion as the z test of the MRI probabilities at level 1 (P1 column), because the latter are the false-alarm probabilities from which the criterion values are obtained. The significance tests for the two, however, are different: MRI is tested by a z test for two probabilities, whereas two criteria are tested with a z test of the converted z values. The two tests may thus produce slightly different results. If this happens, it will probably be due to a marginally significant result of the MRI z test (i.e., significant only at $\alpha = .10$). At this point, the relative power and Type II error rates of the two tests are unknown.

Conditional analyses. In some situations, the marginal results may indicate support for DS, with the conditional results indicating that DS has failed. How should one reconcile these contradictory results? First, one should examine the conditional d' and crit values to see if they are similar and perhaps only marginally significant ($\alpha = .10$). If they are, both DS and PI may be indicated, and the significant outcome can be considered to

be a Type I error. (PI is tested by conditional d' 's, whereas crit values speak to DS.) Note that for a 2×2 feature-factorial design, four statistical tests are performed for each set of conditional estimates.

If the conditional criteria are dissimilar, true failure of DS may be indicated, but probably at a more local level; that is, the decision boundary may be overall straight and parallel to the perceptual axis (marginal DS), yet be curved or even "wiggly" on a smaller scale (conditional estimates indicating $\sim$ DS). If an unambiguous conclusion must be reached, the marginal tests are probably more accurate, given that they are based on more observations (larger N).

Availability. The MSDA_2 program, including sample data and output, are available from a website (<http://www.uvic.ca/psyc/software>). The Pascal 6.0 source code is available from the author on request (e-mail: hkadlec@uvic.ca).

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