A common signal detection model describes threshold and supra-threshold performance

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Psychophysical experiments are typically based on analyzing observer choices as a function of some stimulus dimension in order to make inferences about the underlying sensory and/or decision processes that account for the observer's choices. Modern psychophysical theory derives from Signal Detection Theory (SDT) [1, 2] in which the observer's performance depends on a noise contaminated decision variable that in association with a criterion that determines the rates of both successful classifications and errors. When the decision rule can be characterized as a linear predictor, the framework can be formalized as a Generalized Linear Model (GLM) with a binomial family, facilitating estimating of model parameters by maximum likelihood. The Gaussian, equal-variance model is the most commonly employed which leads naturally to the use of a probit link. The largest body of psychophysical work is based on discrimination of small (threshold) stimulus differences, yielding measures of perceptual strength that do not easily extrapolate to predict performance for large (supra-threshold) differences or for appearance, either.

Some recent techniques do permit an extension of this approach to the supra-threshold domain. For example, Maximum Likelihood Difference Scaling (MLDS) is a psychophysical method and fitting procedure that permits scaling of large stimulus differences based on paired-comparisons of stimulus intervals [3, 4]. In the task, observers are presented with quadruples (or triads) of stimuli distributed along a physical scale. For quads, the observers judge between which pair the difference is greatest; for triads, the judgment is more similar to a bisection task. We review the decision model and the maximum likelihood fitting procedure. Because the decision rule is linear, the fitting procedure can be simplified by reformulating it as a GLM. The **MLDS** package [4] available on CRAN provides tools for fitting and evaluating data sets that arise from these experiments. The resulting scales have interval properties (equal differences along the scale are perceptually equal).

Previous studies have shown that MLDS scales are qualitatively consistent with discrimination performance [5] and that differences along MLDS scales are inversely proportional to reaction times [6]. The decision rule in MLDS is based on an equal-variance, Gaussian signal detection model. We show that when properly parameterized, difference scales also predict the traditional SDT measure of discrimination, d'. We demonstrate this for an experiment in which we used MLDS to quantify the watercolor effect [7], a long-range perceptual filling-in phenomenon. The results imply that a common signal detection model suffices to account for both discrimination performance and appearance. Since SDT provides a common metric for relating threshold behavior to neural response mechanisms, the results have important implications for relating perceptual to neural responses.

Références

[1] Green, D.M., Swets, J.A.(1966/1974) *Signal Detection Theory and Psychophysics.* Robert E. Krieger Publishing Company, Huntington.

[2] Macmillan, N.A., Creelman, C.D. (2005) *Detection Theory: A User's Guide*, 2nd edition, Lawrence Erlbaum Associates, New York.

[3] Maloney, L.T., Yang, J.N. (2003) Maximum Likelihood difference scaling. *Journal of Vision* **3(8)**, 573–585). `http://www.journalofvision.org/3/8/5`.

[4] Knoblauch, K., Maloney, L.T. (2008) MLDS: Maximum likelihood difference scaling in R. *Journal of Statistical Software* **25**, 1–26 `http://www.jstatsoft.org/v25/i02`.

[5] Rhodes, G., Maloney, L.T., Turner, J., Ewing, L. (2007) Adaptive face coding and discrimination around the average face. *ÊVision Research* **47**, 974–989.

[6] Brown, A. M., Lindsey, D. T., Guckes, K. M. (2011). Color names, color categories, and color-cued visual search: Sometimes, color perception is not categorical. *Journal of Vision*, **11(12)**, 1–21, `http://www.journalofvision.org/content/11/12/2`.

[7] Devinck, F., Knoblauch, K. (2012). A common signal detection model accounts for both perception and discrimination of the watercolor effect. *Journal of Vision*, **12(3)**, 1–14, `http://www.journalofvision.org/content/12/3/19`,