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Editorial

A special issue on applications of Signal Detection Theory to visual perception

Like most theories that have wide application, signal detection theory is based upon simple ideas. The stimulus factors that influence perceptual decisions are corrupted by random variations — noise. Observers collect noisy information and distill it down to a single quantity, represented by the decision variable. The value of that variable after a given observation is compared against a criterion value and the result determines the choice of the observer. Thus, according to signal detection theory, to predict the behavior of the observer one needs to understand both the deterministic and random aspects of the stimulus information, the task characteristics that influence the collection and distillation, and the motivational factors that influence the criterion.

These ideas were most famously systematized by Peterson *et al.* (1954) but in vision had been employed earlier. In particular, Hecht *et al.* (1942), and later Baker (1953) and Barlow (1957), were concerned with the photon fluctuations of light and their influences on absolute visual detection. Thus, although signal detection theory is often associated with applications in audition, there is a grand tradition in vision as well.

Students who wish to learn the ideas have a number of excellent reviews available, including in-depth books by Green and Swets (1974), MacMillan and Creelman (1991), and the excellent recent text by Wickens (2002). Specific visual applications are reviewed in the comprehensive book by Graham (1989), the insightful chapter by Nachmias (1972), and a collection of seminal papers edited by Cohn (1993). Thus, the basics can be readily learned but new variations and applications continually emerge; hence the motivation for this special issue of *Spatial Vision*.

Although signal detection theory provides a general framework for analyzing perceptual decision, additional assumptions about the functional relationship between the internal representations and the physical characteristics of external stimuli are required to make specific predictions. The issue has been addressed by the noisy observer approach (Burgess and Colborne, 1988; Eckstein *et al.,* 1997; Lu and Dosher 1999; Pelli, 1981). A number of components, derived from both sensory psychology and physiology, including perceptual template, non-linear transducer, additive noise, multiplicative noise, contrast-gain control, and decision uncertainty, have been used to construct observer models that map the physical description of the stimuli to internal representations. In this special issue, several of these components are re-examined. Miguel A. García-Pérez and Rocío Alcalá-Quintana derive the formal relations between the transducer function, the threshold-versus-contrast (TvC) function, and the psychometric functions for contrast detection and discrimination in 2AFC tasks. The analysis provides insights into the tenability of certain mathematical forms for the psychometric function. The empirical results support the validity of the formal relations implied by the general transducer model. In another paper, Joshua Solomon compares the non-linear transducer approach with the decision uncertainty approach in noisy observer models. Although most empirical results in the literature can be modeled by either of these approaches, Swets *et al.*'s (1961) two-response 4AFC (2R4AFC) detection experiment is an exception. Solomon shows, within the context of a primer on SDT, the uncertainty approach produced an excellent fit to Swets *et al.*'s results; the non-linear transducer model cannot predict the relationship between first- and second-response accuracies. Whether a more elaborated model with a non-linear transducer component (e.g. Petrov *et al.*, 2005) can help remains open.

One of the most intriguing questions in psychology is whether subjects can perceive without awareness. To answer this question, it is critical to develop experimental procedures that objectively measure awareness. Recently, Kunimoto *et al.* (2001) published an SDT-inspired procedure that, according to the authors, allows a bias-free measure of awareness (a') from the confidence ratings in discrimination tasks. In this special issue, Simon Evans and Paul Azzopardi show that, contrary to Kunimoto *et al.*'s intention, a' can vary widely if subjects' response bias varies freely. Although this was not evident in the results of Kunimoto *et al.*'s original experiments, because their method may have artificially 'clamped' observers' response bias close to zero, such variations occurred in a visual discrimination task without constraints on the proportions of low- and high-confidence responses. The authors conclude that Kunimoto *et al.*'s measure is not as impervious to response bias as was originally assumed.

A prime function of vision is recognition of objects at a distance. A great deal of the work on object recognition has focused on the nature of the representation of the object, and especially whether that representation is independent of the viewpoint of the observer. Following up on research by Tjan *et al.* (1995) and others, Martin Demeyer, Peter Zaenen and Johan Wagemans examine the 2-D stimulus properties — rather than properties of the object representation — that might lead to a pattern of viewpoint dependence in object recognition. They vary a 'paperclip' object's properties parametrically, first estimating correlations between image features and next showing that those correlations are consistent with the viewpoint-dependent object classifications of their observers. Their observers recognize objects using a classification rule based upon a weighted combination of stimulus features, with weights that depend upon the variability of the stimulus features and their correlation.

Anna Zalevski, Bruce Henning, and Jeremy Hill also study how stimulus features are combined in making visual judgments. In this case, the task was a judgment of relative depth, or slant. A long-established result is that when judgments of the relative depth, produced by disparity differences, of two vertical lines are made much less precise if the vertical lines are connected by horizontal ones, making a rectangle (Westheimer, 1979). Zalevski and colleagues manipulate perspective and disparity cues and estimate the relative weightings observers give to the combination of cues. The results indicate that even practiced observers sometimes weight cues suboptimally for the task at hand.

Visual object recognition depends, in part, upon recognition of surface spectral reflectance. Color constancy refers to the tendency for the surface color to remain constant across illuminations; despite much research, it is not clear how much color constancy humans actually exhibit, in part because of methodological issues (Foster, 2003). The paper by Just van Es, Tony Vladusich and Frans Cornelissen directly compares a local (perceptual or absolute) color judgment with a relational judgment in a ‘yes/no’ procedure, and uses signal detection as well as other means of analysis. Simulated illuminant changes were of two magnitudes, allowing for the estimation of two d' values and one criterion for each task; these signal detection measures could be compared directly with a more traditional color constancy index. The authors conclude that these results are consistent with others showing higher levels of relational constancy than perceptual constancy.

Independent and objective measures of both perceived size and the distance are critical in distinguishing different theories of the moon illusion, i.e. the elevated moon usually appears smaller than the horizon moon of equal angular size. Based on the size-distance invariance hypothesis, distance cues may enable the perceptual system to place the horizon moon at an effectively greater distance than the elevated moon, thus making it appear as larger. However, the larger horizon moon is usually judged as closer than the smaller zenith moon. This apparent conflict might be due to the bias in assigning shorter distances to closer objects. Using 2AFC procedures, Lloyd Kaufman, Vassias Vassiliades, Richard Noble, Robert Alexander, James Kaufman and Stefan Edlund find that the perceptual distance of the elevated moon is the equivalent of a physical distance of about 19 m. They concluded that the perceived size of the elevated moon is due to the fact that it is located at a lesser perceptual distance than the horizon moon. The result strongly supports the hypothesis that perceived size is proportional to perceptual distance.

The seven articles in this issue represent a small sample of exciting theoretical developments and novel applications of signal detection theory in visual perception.

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