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R_Contrast: Rapid measurement of recognition contrast thresholds

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Abstract—*R_Contrast* is a program for the rapid assessment of recognition contrast thresholds on the PC.

1. INTRODUCTION

The independent assessment of the recognition contrast threshold is of both theoretical and practical importance (Legge *et al.*, 1987; Pelli *et al.*, 1988; Regan, 1988a, b; Strasburger *et al.*, 1991; Alexander *et al.*, 1993; Strasburger *et al.*, 1994; Solomon and Pelli, 1994; Strasburger and Rentschler, 1996). Recognition is understood here as correctly identifying a pattern out of a sizeable number of alternatives, rather than discriminating a small number of alternatives or detecting the mere presence of a stimulus. The contrast threshold is the level of contrast where a specified proportion of correct identifications is obtained and is operationally defined here as the point of inflection on the corresponding psychometric function. *R_Contrast* is a program for the rapid assessment of such recognition contrast thresholds. Using high-resolution numerals as patterns, it has been used extensively to study low-contrast recognition performance in the visual field (Strasburger *et al.*, 1991, 1994; Strasburger and Rentschler, 1996). Possible applications of such measurements are in the areas of experimental psychology, ophthalmology and pediatric ophthalmology, and of neurology and neuropsychology.

2. GRAY-SCALE RESOLUTION

In the past, special hardware was used in order to achieve the required contrast resolution (see Pelli and Zhang, 1991, and Bach *et al.*, 1997, for an overview of low-contrast techniques). A minimum of 9-bit gray-scale resolution is required and 12 bits

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resolution are desirable. Standard PC graphics—the VGA standard—used to have only 6 bits resolution. The need for special hardware has prohibited a wide-spread use of the computer for contrast-sensitivity measurements. In diagnostic purposes in ophthalmology, printed cards for low-contrast recognition measurements are used instead (Pelli *et al.*, 1988; Regan, 1988a, b). Now that 8-bit graphics have become common, software solutions for adding the missing 1–4 bits have come within reach (Tyler, 1997; Bach, 1997). *R_Contrast* currently uses rudimentary, 2-pixel, dithering to achieve 9-bit resolution.

3. STIMULI

The standard stimuli are the 10 numerals, presented in adjustable resolution as multiples of a 5×7 pixel matrix. The patterns can be presented as light on gray or dark on gray. Black and white images in PCX format can optionally be imported such that, for example, optotypes can be used as stimuli. A display option of presenting mirror-imaged targets allows one to view the display through a mirror to increase the viewing distance when small visual angles are desired. Possible presentation times are multiples of the frame duration including presentation for a single frame.

4. THRESHOLDING STRATEGY

A number of adaptive strategies for efficient determination of thresholds have been described (see review in Treutwein, 1995). *R_Contrast* uses the maximum-likelihood technique *ML-PEST* developed by Harvey (Harvey, 1986, 1997). After each subject response, the likelihood for the threshold being at a certain stimulus contrast is calculated on the basis of all previous responses in the current run, and the next stimulus is presented with a contrast where the likelihood function has its maximum. Based on prior information about the slope of the psychometric function, the measurement is stopped after a pre-defined reliability of measurement is attained.

5. CONTRAST DEFINITIONS

The main results obtained from *R_Contrast* are contrast thresholds. For binary-valued patterns like the numerals used in *R_Contrast*, the definition of a measure of contrast is straightforward. However, two different definitions are in common use: Michelson contrast $C_M = (L_p - L_b)/(L_p + L_b)$, where L_p and L_b refer to pattern and background luminance, respectively, and a definition based on the Weber fraction, $C_W = (L_p - L_b)/L_b$; so care must be taken when results are compared between studies. For small contrasts, conversion is simple because C_W is simply twice C_M. At higher contrast levels, however, the proportion varies and is also dependent on contrast polarity. The two measures are related by the one-to-one, non-linear relationship, $C_W = 2C_M/(1 - C_M)$. Results of *R_Contrast* are given in the Michelson measure and can be converted to Weber contrast by the given relation.

6. LATERAL MASKING, CROWDING, ATTENTION

The recognition of patterns is impeded by the presence of neighboring patterns. This effect is referred to as lateral masking or the *crowding effect.* It is found in the fovea but is far more pronounced in peripheral viewing (for a review see Strasburger *et al.*, 1991). Part of the effect can be attributed to limitations of visual attention (Eriksen and Rohrbaugh, 1970; Strasburger *et al.*, 1991). *R_Contrast* can be used to study the crowding effect at contrast threshold by presenting flanking characters with varying lateral distance (Strasburger *et al.*, 1991; Strasburger and Rentschler, 1991). Flanking stimuli are randomly chosen numerals that are different from the target. The program keeps track of whether flanking stimuli were mistakenly reported by the observer. An attentional factor can thereby be isolated by analysis of the recognition errors (Eriksen and Rohrbaugh, 1970; Strasburger *et al.*, 1991).

6. PROGRAM OPTIONS

The program allows several types of measurement, among them (a) acquiring a *stimulus confusion matrix* at fixed contrast and (b) using the method of constant stimuli instead of the adaptive strategy. A companion program (*mlpfit*, Harvey, 1986, 1997) allows maximum-likelihood fitting of a psychometric function to the data acquired by *R_Contrast.*

7. IMPLEMENTATION

The program was originally developed for the PDP-11 (Fortran 66 under the RT-11 operating system), coupled with image-processing hardware and a custom-designed contrast attenuator. That system achieved 15 bits of gray-scale resolution. The program was subsequently ported to Microsoft™ Fortran under DOS on the PC, using newly developed contrast-attenuation hardware with similar resolution. Recently, the program was modified to link to the *PXL* library (Jüttner and Strasburger, 1996; Irtel, 1996) and thereby support standard-VGA graphics boards. As a consequence, special hardware is no longer required at the cost of having reduced contrast resolution (i.e. 9-bit).

8. AVAILABILITY

The program is available free of charge from the author.

9. HARDWARE REQUIREMENTS

The program runs on standard IBM PCs and compatibles (386 and upwards), under MS-DOS or in a DOS window under Windows™. A 'true color', i.e. 3×8 bit, graphics board is required.

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