

## Letter identification performance is better for negative contrast than positive contrast

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### Introduction

Scharff and Ahumada (2002) measured text readability for positive and negative contrast text on a plain background at two contrast levels, 30% and 45%. The observer's task was to find a target word (triangle, circle, or square) in a text paragraph as illustrated in Figure 1.

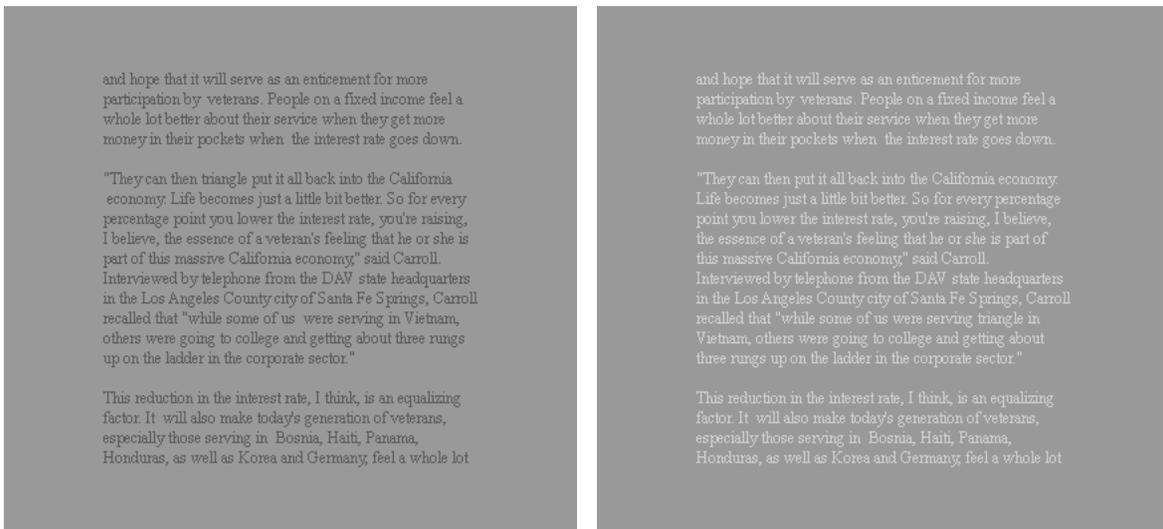


Figure 1. 45% contrast texts from Scharff and Ahumada (2000), negative (left) and positive (right).

Scharff and Ahumada (2003) measured the identifiability of the individual letters cut out from those target words. Both studies found better performance for negative contrast stimuli as shown in Figure 2.

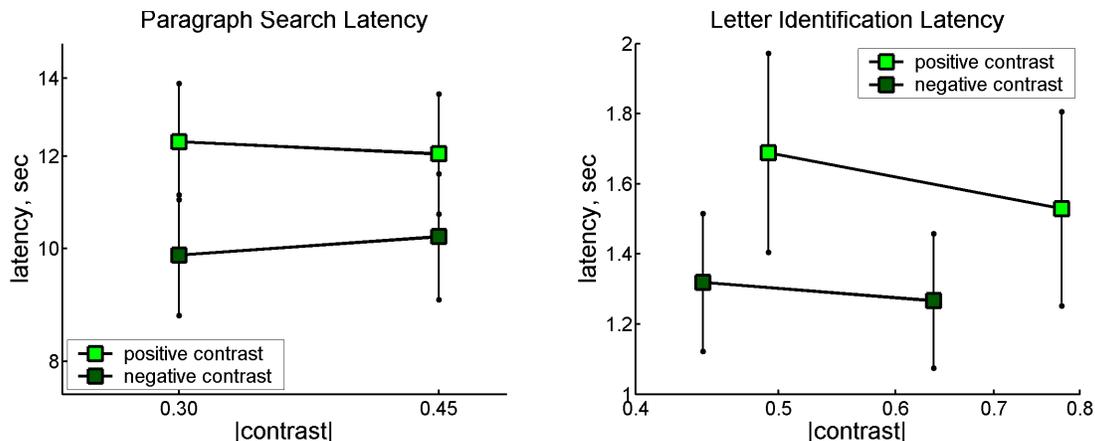


Figure 2: Response latencies vs. contrast for the paragraph word search task data (left) of Scharff and Ahumada, (2000) and the letter identification task data (right) of Scharff and Ahumada (2003). Error bars indicate 95% confidence intervals based on observer variance in each condition.

## Hypotheses

Some possible reasons for the improved performance for negative contrast text include the following:

Separate gain hypothesis. The positive contrast system has lower gain than the negative contrast system (result opposite that reported by Chan and Tyler (1992)). Beginning with the retinal level, the positive and negative contrast systems have different anatomical structures (Kolb, Fernandez, and Nelson, 2001), thus there is no reason to expect them to have the same gain.

Fechnerian brightness hypothesis. Internal measures of contrast are computed from a “brightness” measure that is negatively accelerating with respect to luminance (Whittle (1986, 1992), Kingdom and Moulden (1991), Belaïd and Martens (1998)).

Dark screen matrix hypothesis. Pixels on the screen are made of a small number (~1) of dot triads on a dark matrix. The dark matrix and the blue dots form low luminance boundary regions that are assimilated to the negative contrast regions. This can only occur when the contrast regions are above threshold locally.

Display nonlinearity hypothesis. Single light pixels following a background pixel are more like the background than are dark pixels because video amplifiers have a slower rise time than fall time. This caused the old VT100 text with dim vertical strokes and bright horizontal strokes.

Under the separate gain hypothesis, but not the others, the polarity effect should persist at low contrasts, so we measured the effect at lower contrasts.

## Methods



Figure 3. The twelve letter images at -40% contrast.

Observers were asked to identify the Scharff & Ahumada (2003) twelve lower case letters (acegilnqrstu) on a uniform background (Figure 3). At their narrowest, the vertical strokes were one pixel wide. A letter remained onscreen until the participant typed a response. Within each block of 36 trials, each letter was presented at 3 contrast levels: 10%, 20%, and 40%. Six observers ran the 5 negative contrast blocks first; seven observers ran the 5 positive contrast blocks first.

The letters were displayed on a NEC Accusync CRT monitor with a 0.28 mm dot trio pitch at a display resolution of approximately 0.26 mm per pixel (effectively one pixel per dot trio). The viewing distance was about 47 cm (forehead rest).

To test display linearity, we constructed six images, photometrically measured their average luminance, and computed their contrast with respect to the background luminance. Two were vertical line images. Image (2:1) pixel columns alternated between the background level (0% contrast) and the +40% contrast level; in image (4:1) +40% pixel columns sandwiched 3 background pixels; and image (1:1) contained only +40% pixels. We also constructed the -40% counterpart images. The resulting contrasts, shown below, do not reveal any appreciable nonlinearity.

image	1:1	2:1	4:1
+contrast	+38.5%	+19.1%	+10.1%
-contrast	-41.6%	-22.0%	-10.5%

## Results

As Figure 4 shows, both performance measures, latency and accuracy, were better for the negative contrast conditions at 20% and 40% contrast, but were not different at 10% contrast, even though the accuracy performance was better than chance.

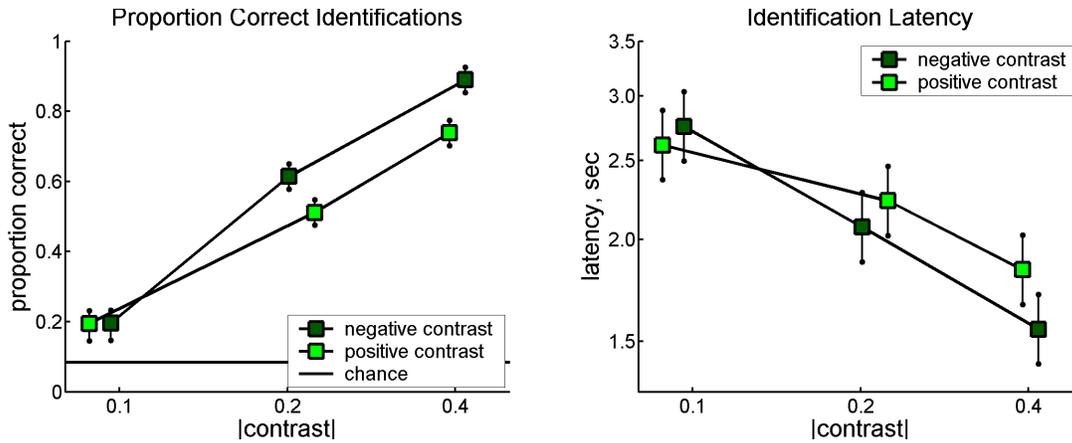


Figure 4: Letter identification accuracy plotted against the absolute value of letter contrast (left). Letter identification latency plotted against the absolute value of contrast (right). Error bars are 95% confidence intervals based on the observer by treatment interaction, except for the lower bars on the 0.1 contrast points in the accuracy figure (left) that are based on the pooled observer variance for those points to allow comparison with chance performance.

For the 20% and 40% conditions, we used linear interpolation (in log contrast) to find the contrast of the other polarity with the equivalent accuracy (left graph). This opposite polarity contrast and the original contrast were used to determine the ratio of the effectiveness of positive contrast to that of negative contrast:

$$\begin{aligned}
 +20\%: 0.70, & \quad +40\%: 0.74, \\
 -20\%: 0.75, & \quad -40\%: 0.72.
 \end{aligned}$$

The mean of the four estimates is  $0.726 \pm 0.036$  (95% confidence interval).

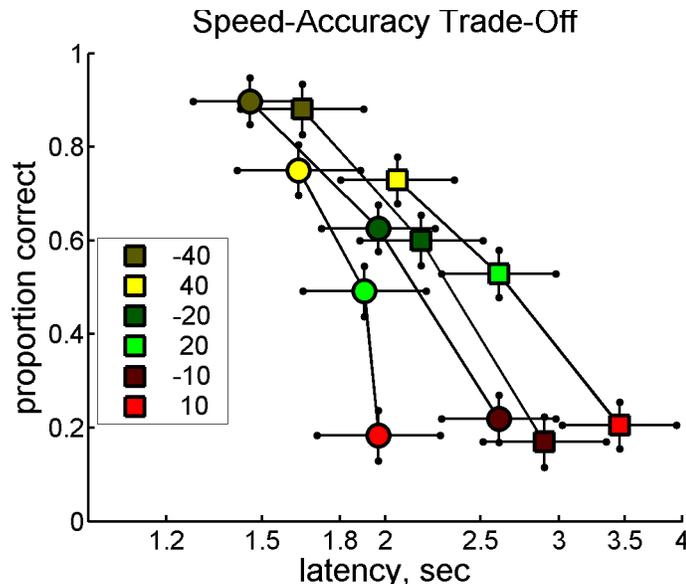


Figure 5: Letter identification accuracy vs. latency (speed-accuracy trade-off). Square symbols indicate conditions run in first group of 5 blocks. Circles indicate second group of 5 blocks. Colors indicate the contrast in per cent. Error bars are 95% confidence intervals based on the observer x treatment interaction.

The speed accuracy trade-off graph (Figure 5) shows that while combined speed-accuracy performance was better in the second set of 5 blocks (circles), the observers did not improve in accuracy; they shortened their latencies instead. In the first blocks (squares), the observers given the more difficult positive contrast task (light squares) took more time to be more accurate, but when this task was second (light circles), observers gave it even less time than was given by the other observers doing the easier task second (dark circles).

## Conclusions

The contrast gain asymmetry for letter asymmetry persisted at contrasts of 20% and 40%, but was not measurable at 10%, weakly failing to support the separate gain hypothesis.

The screen calibration results do not support the display nonlinearity hypothesis. We would like more direct measures of luminance modulation depth.

We are collecting data at twice the pixels per letter, but the same letter size in visual angle, since the Fechnerian brightness hypothesis predicts no effect of this manipulation, while the dark screen matrix hypothesis predicts a strong drop in the effect.

The speed-accuracy trade-off effects were strong, so we plan to redo the contrast ratios using a combined accuracy-latency measure. As signal detection theory taught us that false alarms are necessary to measure detectability, speed-accuracy trade-off theory should remind us that errors are necessary to estimate performance in the presence of possible trade-off effects.

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