

Letter Identification: Contrast Polarity and Speed-Accuracy Trade-Off Strategies

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Summary

Observers were asked to identify which of 12 letters was presented on a uniform background. The letters varied in contrast polarity (positive vs. negative) and in contrast relative to the background (10%, 20%, or 40%). To allow observers to maintain a consistent perceptual strategy for each polarity, each observer ran the polarity conditions blocked, first 5 replications of all three contrast levels at one polarity, then the other. Both latency and percent correct scores in general showed better performance for negative polarity. However, strong differences in the speed-accuracy trade-off strategies appeared across polarity for the two groups of observers. The observers who had the more difficult positive polarity first, took more time (had longer latencies), but the observers who had the more difficult polarity second, took less time. Combined speed-accuracy scores helped to measure the increased identifiability of the negative contrast letters over that of the positive contrast letters in the presence of the changing strategies.

Introduction

Our previous experiments on text readability and letter identification (Scharff and Ahumada, 2002; 2003a) measured performance for positive and negative contrast text on a uniform background. Both studies found better performance for negative contrast stimuli than positive contrast stimuli. We decided to repeat the letter identification study (Scharff and Ahumada, 2003b) with more careful control of the contrast so that we could include an accurate contrast polarity factor in our quantitative index of text readability.

Methods

Observers were asked to identify the Scharff & Ahumada (2003a) twelve lower case letters (acegilmqrstu) on a uniform background. 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.

Results

As Fig. 1 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.

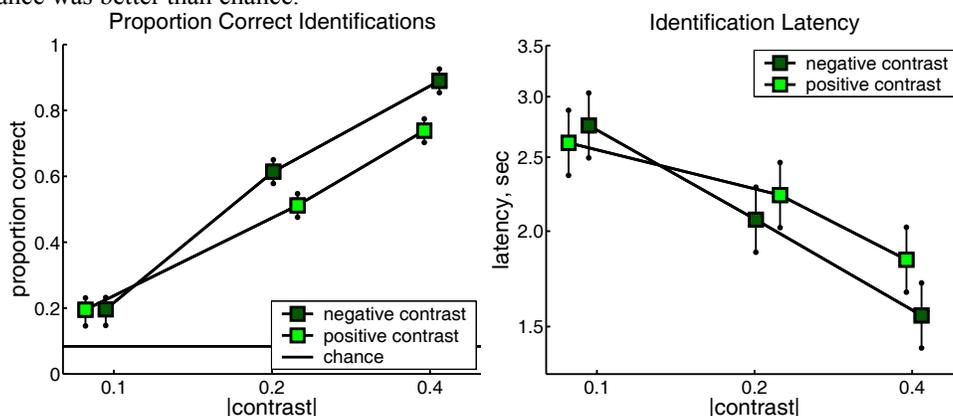


Fig. 1: Left: Letter identification accuracy vs. contrast. Right: Letter identification latency vs. contrast. Error bars are 95% confidence intervals based on observer x treatment interaction, except for the lower bars on the 0.1 contrast points in the left figure that are based on the pooled observer variances for those points to allow comparison with chance.

The speed accuracy trade-off graph (Fig. 2) 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 positive contrast task was second (light circles), observers gave it even less time than was given by the other observers doing the easier negative contrast task second (dark circles).

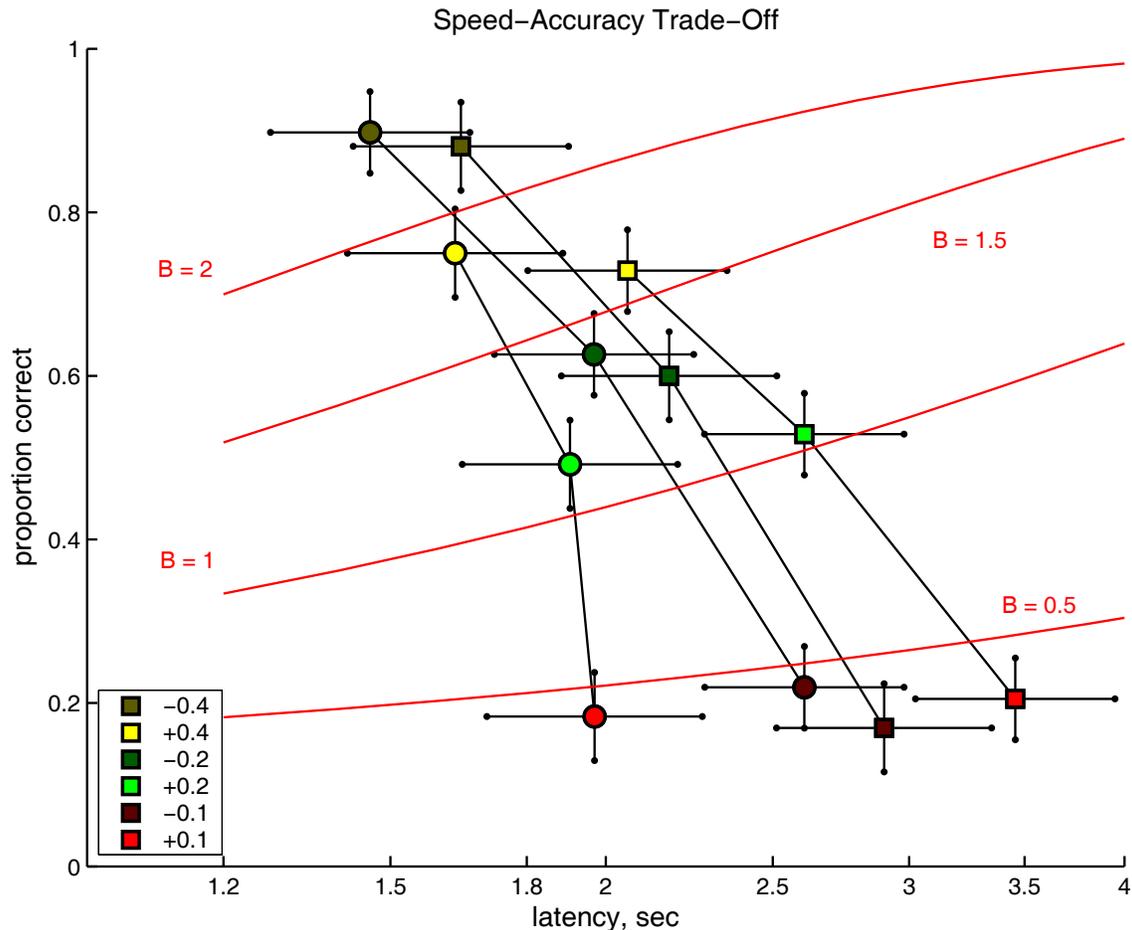


Fig. 2: Letter identification accuracy vs. latency (speed-accuracy trade-off). Square symbols indicate conditions run in first group of 5 blocks. Circles indicate second group of 5 blocks. Colors indicate the contrast in percent. Error bars are 95% confidence intervals based on the observer x treatment interaction. Red lines show constant performance curves for our speed-accuracy trade-off model.

Speed-Accuracy Trade-Off Assumptions

1) The detectability d' of the stimuli increases as the square root of the observation time,

$$d' = B T^{0.5},$$

where T = the observation time (observer's latency). B , the 'rate' of information accumulation, is fixed for a given stimulus condition.

2) The differences among the 12 signals are orthogonal and equally detectable so that the probability of a correct response P_C can be computed from d' by the approximation

$$P_C = F(0.87 d' - 1.38),$$

where $F()$ is the cumulative standard normal distribution function, and the approximating constants are from Elliott (1964).

The red lines in Fig. 2 are the speed-accuracy trade-off lines for $B = 0.5, 1, 1.5, 2$.

Fig. 3 shows the average **B** estimates as a function of contrast and polarity.

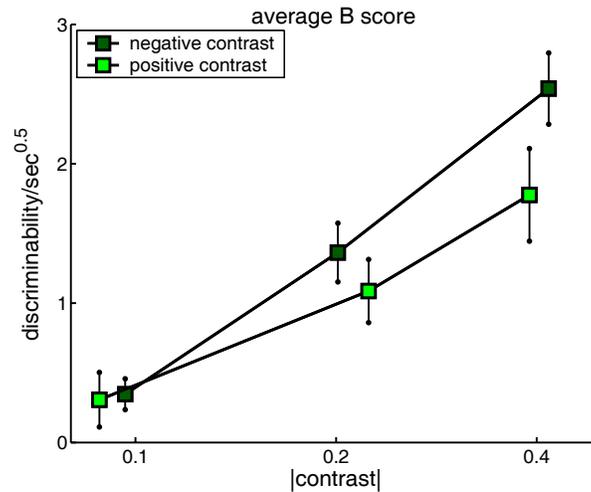


Fig. 3: Average combined speed-accuracy scores **B** as a function of contrast and polarity for comparison with Fig. 1. Error bars are 95% confidence intervals based on pooled group variance at each contrast. The polarity effect at the high contrast is now larger in effective contrast.

Conclusions

Scores combining speed and accuracy show a different interaction of the polarity effect with contrast than latency or accuracy alone and generate larger ANOVA *F*'s for the polarity effect.

As signal detection theory asks for experiments to have false alarms and uses them to estimate detectability, speed-accuracy trade-off theory asks for non-zero error rates and provides measures of detectability that combine speed and accuracy.

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References

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Appendix

Matlab routines for computing the speed-accuracy trade-off curves and the measure **B**.

```
function Pc = sat(T, B, T0, n, an, bn, Pe)
% speed[latency](T)-accuracy(Pc) trade off curve
% B = d' for 1 time unit
% T0 = part of response time that information is not being accumulated
% n = number of response alternatives
% an, bn = constants to approximate Pc(dprime,n)
% Pe = "finger error" probability
dprime = B*sqrt(T-T0) ;
Pc = (1/n)*Pe + (1-Pe)*Fnorm(an*dprime - bn) ;
% The routine sat may be used to plot points (T, Pc(T))
% for a constant information 'rate', B.
% We assume that the detectability dprime increases proportionately to
% the square root of the time spent accumulating information TI
% dprime = B/sqrt(TI)
% We assume the latency is a constant plus the accumulation time
% T = T0 + TI
% We assume that dprime can be converted to a probability correct
% according to the number of response alternatives.
% Pc' = f(dprime, n)
% This function can be approximated by
% Pc' = Fnorm(an*dprime - bn),
% where a12 = 0.87 (Elliott (1964) p. 681) and
% Fnorm(-bn)=1/n. So b12 = -znorm(1/12) = 1.3830
% We allow for a finger error rate so that the observed rate of correct
% responses is
% Pc = (1/n)*Pe + (1-Pe)*Pc'
% Test: T = 2; B = 1; T0 = 1; n = 12; an = 0.87; bn = 1.383; Pe=0.05
% Pc = 0.2929 ; Fnorm(1/sqrt(2)) = 0.76

function B = satB(Pc, T, T0, n, an, bn, Pe)
% speed[latency](T)-accuracy(Pc) trade off measure
% B = dprime for 1 time unit
% T0 = time that information is not being accumulated
% n = response alternatives
% an, bn = constants to approximate Pc(dprime,n)
% Pe = finger error rate
Pcu = (Pc - Pe/n)/(1-Pe);
B = ((bn + znorm(Pcu))/an)./sqrt(T-T0) ;
% from sat.m
% dprime = B*sqrt(T-T0) ;
% Pc = (1/n)*Pe + (1-Pe)*Fnorm(an*dprime - bn) ;
% Test:
% Pc = 0.2929 ; T = 2; T0 = 1; n = 12; an = 0.87; bn = 1.383; Pe=0.05
% B = 0.9998

function val = Fnorm(z)
val = 0.5*(1+erf(z/1.41421356237310));

function val = znorm(p)
val = 1.41421356237310*erfinv(p+p-1);
```