TRUE TO LIFE: THE ROLE OF BASE RATE AND WORD-COLOR CORRELATION IN ENGENDERING THE FAILURE OF SELECTIVE ATTENTION

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Abstract

Presented with color words printed in various colors, participants can attend selectively to the words but cannot attend selectively to the colors. This failure of selective attention, known as the Stroop effect, is the single most popularly studied phenomenon in current cognitive science. Recent studies demonstrated the effect of color-word correlation on the Stroop effect, thereby challenging accounts of automatic reading. However, virtually all Stroop studies to date employed equal base rates of colors and color words, which may not reflect real-life probabilities. Uneven base rates can, in turn, influence performance, favoring semantically congruent or incongruent stimuli. In a series of experiments, we tested the effect of base rate in tandem with that of color-word correlation. The results showed that marginal frequencies affect selective attention and must be taken into consideration when designing or interpreting future studies.

The Stroop phenomenon (Stroop, 1935) documents the failure to attend selectively to a dimension of a complex stimulus. When people are asked to name the ink color in which color words appear, naming performance is affected by the meaning of the words. When the word and the color are congruent (e.g., the word RED printed in red ink) color naming is fast, whereas when the word and the color are incongruent (the word RED printed in green ink) color naming is slower. The Stroop effect (SE) is the difference in color naming performance between incongruent and congruent stimuli. Notably, reading the words is not similarly affected by the irrelevant print color. This asymmetry is commonly interpreted as tapping the automatic processing of the words. People are unable to avoid reading words exposed for view for whatever purpose.

However, recent studies indicate an unexpected plasticity of the Stroop phenomenon (Melara & Mounts, 1993; Melara & Algom, 2003). These studies have demonstrated that contextual factors govern the size, direction, and even the very appearance of the SE. In this work, we focus on one such variable of context, the correlation over trials between word and color. If there is a correlation between color and word, then the nominally irrelevant word actually predicts the target color and engenders the failure of selective attention to color (Dishon-Berkovits & Algom, 2000; Logan & Zbrodoff, 1979; Melara & Algom, 2003). However, all Stroop-correlation studies to date have employed equal numbers of the various colors and color words. What happens when the base rates are unequal? The fine interplay

between correlation and base rate in determining selective attention formed the topic of this research.

Dimensional correlation is fatal for selective attention. If there is a correlation between color and word built into the experiment, one dimensional value carries information about the other and thus diverts attention toward the irrelevant dimension. Typically, experimenters balanced the number of congruent and incongruent stimuli in their study. This practice ignores the fact that there are more incongruent then congruent stimuli in the Stroop design. With four ink colors and four color words combined in a factorial fashion, there are four congruent but twelve incongruent combinations. Presenting them in equal numbers means that each word appears in a matching color more often than it does in a mismatching color, so that the word predicts the color. The conditional probability of a color given its matching word is greater than that of any other color. Observers notice the predictive relationship, and the information thus provided jeopardizes selective attention. Dishon-Berkowits and Algom (2000) showed indeed that when the stimulus values along the target dimension and the to-be-ignored dimension were correlated over the experimental trials, large effects of Stroop interference influenced performance. However, when random allocation of values created zero dimensional correlation, the SE vanished.

Notably, in the vast majority, if not all Stroop studies, equal base rates for words and colors were used. However, in everyday life, stimuli seldom appear at equal frequency. In the summer there are more hot than cool days. These uneven base rates can be used for prediction. In the summer it is fairly safe to say that tomorrow will be a hot day. People do notice the correlation between a cloudless sky and high temperature. However, this correlation is virtually useless during the summer because of the high base rate of warm days. The same correlation is valuable in a season (spring) when cold and warm days alternate with nearly equal frequency.

Kareev, Fiedler, and Avrahami (2009) have indeed demonstrated that unequal base rates often render correlation unnecessary. High base rate events can be predicted and relied upon without ever understanding or explaining the conditions under which they occurred. Correlation becomes valuable when the base rate distribution is more even.

In this study, we examined the joint effect of base rate and correlation on the SE. Correlation within the Stroop design simply means that there is an unequal frequency of congruent and incongruent combinations. Unequal/skewed base rate means that there is an unequal frequency of the various colors and words presented. With two colors (red, green) and two words (RED, GREEN), 80% of the colors can be red and only 20% green. These unequal rates can favor congruent combinations so that most of the color words appear in their matching color (RED in red). On the other hand, base rate can favor incongruent combinations (when GREEN in red appears on the majority of trials).

In this study we systematically manipulated the base rate and correlation of words and ink colors within the Stroop design. The task was speeded color naming.

EXPERIMENT 1

Method

Participants

The participants were 20 undergraduate students from the Department of Psychology, Tel Aviv University, who volunteered to take part in the experiment in partial fulfillment of course requirements. All participants were native Hebrew speakers and had normal or corrected-to-normal vision.

Stimuli and Apparatus

We used 6 color words (the Hebrew words for RED, GREEN, BLUE, BROWN, PURPLE, and PINK) and their corresponding ink colors. The words were presented in Arial font size 18, over a grey background. Stimulus presentation and measurement were governed by a DirectRT Precision Timing Software (Version 2008.1.0.11). The stimuli were displayed on a 17 in. color monitor set to a resolution of 1,024 x 768 pixels. A Logitec external headset with a microphone, fitted to each participant, collected the vocal responses. The participants were sitting approximately 60 cm from the screen, so that the words subtended a maximum of 5.4 degrees of visual angle in width and 1.52 degrees in height. The word appeared at the center of the screen and remained visible until the participant's vocal response.

Design

Three levels of correlation ($r = 0$, $+0.5$, or -0.5) were combined with three levels of base rate [even, uneven favoring congruent stimuli (60%), and uneven favoring incongruent stimuli (60%)] to produce 9 Stroop conditions. Each condition entailed 2 (words) x 2 (colors) matrix. Different pairs of colors and color words were used on each block.

Procedure

The participants were tested individually. Each participant performed in all 9 Stroop experiments defined by the particular color-word correlation and the particular frequency of the words and colors used. The order of the experiments and the color-words used in each were determined in a random fashion for each participant. The task for the participant was to name the ink color. Filler tasks (spatial decision tasks and arithmetic exercises) separated between consequent experiments.

Results and Discussion

Figure 1 gives the SE for all combinations of correlation and base rate. Clearly, the SE was affected mainly by correlation. The greater the correlation the greater the SE. Base rate affected the SE only when correlation was positive. Because the effect of base rate was small and not readily interpretable, we attempted to gauge it in another experiment.

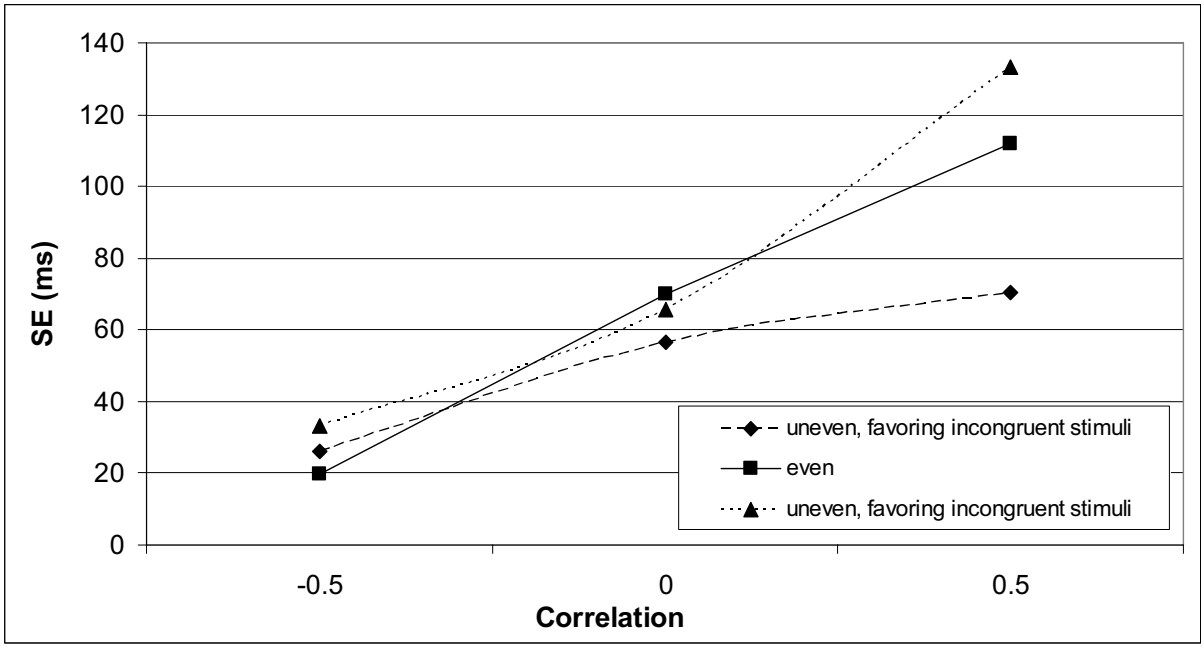

Figure 1: The Stroop effect as a function of color-word correlations and base rate frequencies of the colors and the words.

EXPERIMENT 2

The results of Experiment 1 showed a fairly limited effect of base rate. In order to get more evidence on the role, if any, of base rate, we decided to hold correlation constant (at zero) in this experiment. In addition, we used more extreme values of base rates (75%).

Method

Participants

The participants were a new group of 15 undergraduate students from the Department of Psychology, Tel Aviv University, who volunteered to take part in the experiment in partial fulfillment of course requirements. All participants were native Hebrew speakers and had normal or corrected-to-normal vision.

Stimuli and Apparatus

The same stimuli and apparatus from Experiment 1 were used in this experiment.

Design

The design of this experiment was the same as that of Experiment 1 with two notable exceptions. We held color-word correlation constant at zero, and manipulated only the levels of base rate.

The levels were more extreme, at 75%, than the values in Experiment 1. Therefore, there were 3 blocks of trials in Experiment 2, defined by base rate: even, uneven favoring congruent stimuli (75%), and uneven favoring incongruent stimuli (75%).

Procedure

Each participant performed in all 3 conditions. Otherwise, the procedure of this experiment was similar to that of Experiment 1.

Results and Discussion

Figure 2 gives the results of Experiment 2. The influence of base rate is salient to visual inspection. When correlation is no longer a factor, the relative frequency of the words and the colors used made a big difference. When the skewed base rate favored congruent stimuli, the SE increased relative to the even base rate condition. When the skewed base rate favored incongruent stimuli, SE decreased relative to the even base rate condition.

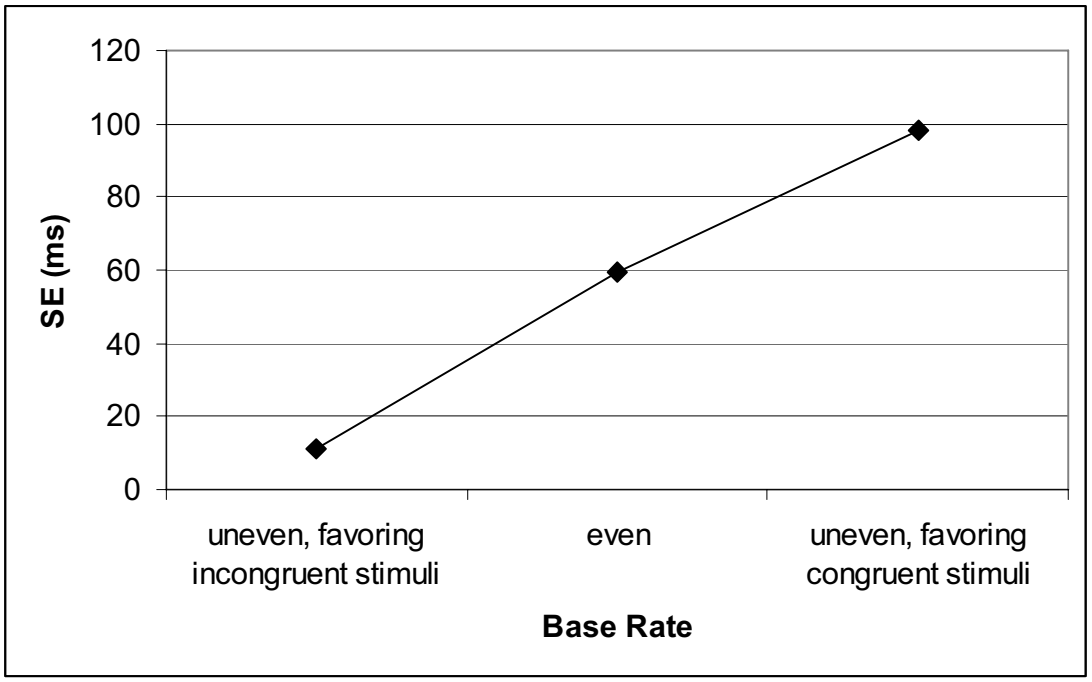

Figure 2: The Stroop effect as a function of the base rates of colors and words.

Conclusions

The results with respect to correlation largely replicated previous findings. One feature to notice is the asymmetry between positive and negative correlation. Only positive correlation enhances the SE. However, the truly novel contribution of this study concerns the effect of base rate. This

variable has been neglected in the Stroop literature. It was assumed to be even without justification. Our results show that uneven base rates affect performance and must be considered in future studies. The full impact of base rate and the precise forms of its influence should be revealed in subsequent research.

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