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Hemispheric asymmetry in the processing of Stroop stimuli

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Subjects responded to Stroop (incongruent color and color word) and non-Stroop (congruent color and color word) stimuli, presented to the left or right visual field, under four instructional conditions (color, word, memory color, memory word). The typical Stroop effect was present in the simple conditions (color, word) with no hemispheric asymmetry. In the memory conditions, there was hemispheric asymmetry in the Stroop effect, with reduced interference in the right hemisphere for memory color responses, and in the left hemisphere for memory word responses. The difference in results was attributed to the possibility for selective attention to a target, rather than a dimension, in the memory conditions.

The well known Stroop effect (interference in naming the ink color of a color word written in a conflicting color ink) occurs because subjects typically cannot avoid processing the irrelevant dimension, with consequent competition between the response to the printed word and the ink color (Dyer, 1973).

Schmit and Davis (1974), using a small set of stimuli and a buttonpress response, investigated the effect of visual field of presentation on Stroop interference. Reasoning that only the dominant hemisphere should have access to verbal information, they predicted a reduction in the Stroop effect for stimuli presented to the nondominant hemisphere under instructions "respond to color," relative to instructions "respond to word." They failed to find the predicted interaction. The inability to reduce Stroop interference under these conditions is consistent with the interpretation of Posner and Snyder (1975) that access to the physical and name code of both dimensions of Stroop stimuli is an automatic process, operating in parallel and without interference until close to the output.

The central question of this study is: under what conditions, if any, can this automatic process come under strategy control? Treisman (1969) suggested a distinction between selectively attending to a perceptual dimension and selectively attending to a target, or critical set of features. She reviewed ample eivdence that target selection is possible, but concluded that there is relatively little evidence that attention can be restricted to a perceptual dimension. Her interpretation was that the typical Stroop effect reflects this difficulty.

In the present study, the dimensional nature of the Stroop stimulus set was reduced to the colors red and blue, and the printed words "red" and "blue," combined to yield a four-stimulus set: two congruent non-Stroop stimuli, and two noncongruent Stroop stimuli. Subjects performed a modified version of the Stroop test, using a keypress response, under each of four instructional conditions. In the first two conditions, color and word, subjects received the typical instructions "respond to color," or "respond to word." These conditions were considered a strong test of the automatic processing of the physical and name code of dimensional stimuli, since a naming response was not required, and with the small stimulus set an optimal strategy would be to process only the physical features and avoid interference. In the other two conditions, memory color and memory word, subjects were instructed to respond "same" if the value (red or blue) of the attended dimension was the same as on the previous trial and "different" if it was different. In these conditions, subjects could possibly restrict attention to the target value of the dimension, and thus, according to Treisman's (1969) analysis, avoid Stroop interference. Visual field of presentation was included as a variable in all conditions, both as a replication of the Schmit and Davis (1974) experiment and because it seemed reasonable that a reduction in Stroop interference would be more likely to occur in the appropriate hemisphere

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(i.e., left hemisphere for word conditions and right hemisphere for color conditions).

METHOD

Subjects were 12 right-handed Duke University students who were paid for participation. Subjects were seated in a sound-attenuated chamber before a viewing screen 5 ft away.

Stimulus materials consisted of a 160-trial partially random series of four Stroop slides (two congruent: word red printed in red, word blue printed in blue; and two noncongruent: word red printed in blue, word blue printed in red). Slides were presented at a 3-sec rate, for 50-msec duration, and 5 deg either to the left or to the right of a fixation point. Half the slides of each type were presented in the left visual field and half in the right visual field.

Subjects performed a modified version of the Stroop test under each of four conditions. In the color condition, subjects responded to the color of the stimulus by pressing a left- or right-hand key to indicate red or blue, with the printed word irrelevant. In the word condition, subjects responded to the printed word with the appropriate keypress, with color irrelevant. In the memory color condition, subjects responded "same" if the color of the current slide was the same as the color of the previous slide and "different" if the color of the current slide was different from the previous slide, again with the appropriate keypress. In the memory word condition, subjects responded "same" if the printed word was the same as the word on the previous slide and "different" if the word was different.

Under each condition, there was a 160-trial practice series, followed by a 160-trial test series. Only the reaction times to the test series were recorded and scored. Individual error rates were less than 10% under each condition. The order of conditions and the assignment of responses to keys were counterbalanced across subjects, with the constraint that the two simple conditions and the two memory conditions always occurred in sequence.

RESULTS AND DISCUSSION

Mean reaction times as a function of condition, stimulus type (congruent, noncongruent), and visual field (left, right) are presented in Table 1. Each mean is based on the mean number of correct trials per subject per cell. Results were analyzed using a multivariate analysis-of-variance program for repeated measures, but all F values are reported for the univariate F. Because of the difference in the dependent measures, reaction times for the two simple conditions (color, word) and for the two memory conditions (memory color, memory word) were each analyzed as separate three-factor ANOVAs.

In the simple conditions, color and word, condition had a significant effect $[F(1,11) = 7.37, p < .02]$. Reaction times to the color dimension were faster than reaction times to the word dimension. Visual field of presentation also had a main effect. Overall, stimuli presented to the right visual field (left hemisphere) resulted in faster reaction times $[F(1,11) = 6.37, p < .03]$. Of more interest was the significant effect for stimulus type. In spite of the limited stimulus set and the keypress response, there was a significant Stroop effect. Noncongruent stimuli resulted in longer reaction times than congruent stimuli $[F(1,11) = 38.72, p < .0001]$. No interactions were significant. In particular, there was no interaction of visual field with either condition or stimulus type. This is consistent with the assumption that subjects attend to the stimulus dimension, rather than to target values of the stimuli, and under these conditions cannot avoid automatic processing of both the physical and name codes of the color and word dimensions.

In the memory conditions, the main effects of condition and visual field were not significant. The main effect of stimulus type was significant $[F(1,11) = 9.82, p < .01]$, indicating a robust Stroop effect in the memory conditions. However, the three-way interaction of condition, stimulus type, and visual field was also significant $[F(1,11) = 6.45, p < .03]$. Inspection of the means in Table 1 shows that Stroop interference was reduced for stimuli presented to the right visual field (left hemisphere) under the memory word condition and eliminated for stimuli presented to the left visual field (right hemisphere) under the memory color condition. No other interactions were significant.

The marked hemispheric asymmetry of the Stroop effect in the memory conditions and the absence of this asymmetry under the simple conditions suggest several hypotheses about the processing in the two tasks. First, it is apparently impossible in either task for subjects to restrict processing to the physical features of the stimulus and completely avoid Stroop interference. This supports the assumption of Posner and Snyder (1975) that access to the physical and name codes of Stroop stimuli is an automatic process.

To account for the hemispheric asymmetry of the Stroop effect in the memory conditions, it appears necessary to assume that there is some preferential access to word codes in the left hemisphere and to color codes in the right hemisphere. When attention is directed toward a particular target value of the relevant stimulus dimension, as in the memory conditions, the usual interference from automatic processing of irrelevant stimulus features can be avoided, but only when stimulus processing is initiated in the preferred hemisphere for the selected stimulus feature.

Table 1
Mean Reaction Times (in Milliseconds) to Stroop (S) and non-Stroop (NS) Stimuli, as a Function of Instructional Condition and Visual Field of Presentation

	Right Field (Left Hemisphere)		Left Field (Right Hemisphere)	
Condition	NS	S	NS	S
Color	442	462	452	478
Word	473	484	478	492
Memory Color	491	538	536	532
Memory Word	538	549	531	562

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