Notes and Comment

On a variant of Stroop's paradigm: Which cognitions press your buttons?

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The Stroop effect typically refers to the fact that the time to identify the color of a visually presented word is affected by the relationship between the word and the color. When the (irrelevant) word is semantically related to the color (e.g., the word green, presented in red) response time is slower than if the word is neutral or unrelated. One question that has been posed concerns whether semantics plays a role only when the task requires an explicit verbal response, or whether it also plays a role when the response is manual. Sharma and McKenna (1998) have reported that semantics plays a role only when the response is vocal. A reanalysis of their data shows that semantics also plays a role when manual responses are made.

It is well established that identification of the color of an incongruent word (e.g., green letters spelling the word *red*) is slower than the identification of the color of a congruent word (e.g., red letters spelling the word *red*). This Stroop effect and its many variants have been explored in more than 500 papers over the past 60 years (MacLeod, 1991; Stroop, 1935). One account is that *semantic* activation of a word interferes with the identification of and/or the response to the ink color (e.g., Davelaar & Besner, 1988; Klein, 1964; Klopfer, 1996; Posner & Snyder, 1975; Williams, Mathews, & MacLeod, 1996). The present note addresses the issue of whether semantic processing plays a role in both vocal and manual responses to a version of "the" Stroop task, with particular reference to Sharma and McKenna's (1998) conclusion that a semantic contribution to performance in one variant is restricted to vocal responses.

Sharma and McKenna (1998) reported an experiment in which response modality (vocal vs. manual) was one factor and semantic status of the irrelevant letter string was another factor with five levels. These levels were (1) a repeating letter string (e.g., XXXX, OOOO, HHHH, PPPP), (2) neutral words (e.g., *top*, *chief*, *club*, *stage*), (3) color-related words (e.g., *grass*, *fire*, *sky*, *bear*), (4) color words not in the response set (e.g., *purple*, *gray*, *gold*, *yellow*), and (5) color words in the response set (e.g., *red*, *green*, *blue*, *brown*). These conditions were

blocked. Subjects were instructed to ignore the irrelevant letter string and to either name the color aloud (in one block of trials) or identify it with a keypress (in another block). As can be seen in Figure 1, the ordering of conditions across the vocal and manual responses is identical in terms of their effect on response time (RT).

We ignore the repeated letter condition here since it has no lexical/semantic status.¹ RTs are fastest in the neutral word condition, and then they systematically slow in accord with the irrelevant word's semantic status: RTs to color-related words were next, followed by those to color words not in the response set, and finally, those to incongruent color words that belonged to the response set. Sharma and McKenna (1998) report that, for the *vocal* response condition, neutral words (2) (e.g., *top*) are faster than color-related words (3) (e.g., *grass*), which, in turn, are faster than color words not in the response set (4) (e.g., *purple*), which, in turn, are faster than color words that belong to the response set (5) (e.g., *red*).

Sharma and McKenna's (1998) analysis of the manual response condition produced a different outcome. Here, RTs to neutral words (2) (e.g., *top*) did not differ significantly from color-related words (3) (e.g., *grass*), which, in turn, did not differ from color words not in the response set (4) (e.g., *purple*). Color words not in the response set (4) (e.g., *purple*) were faster than color words that did belong to the response set (5) (e.g., *red*). Sharma and McKenna therefore concluded that a lexical/semantic component does not produce interference in a Stroop task requiring a manual response "for manual [word] responses... There were no significant effects of... semantic relatedness... or semantic relevance" (Sharma & McKenna, 1998, p. 1038).

The difficulty here is that Sharma and McKenna (1998) implicitly accepted that there was no difference between conditions (2) and (4), despite the fact that this 42-msec difference was very close to the conservative 42.6-msec Tukey HSD critical value. Given that semantic relevance and semantic relatedness both index a potential semantic contribution to the Stroop effect, a more powerful method of assessing semantic involvement is to perform a trend analysis. If there is a semantic contribution to performance in the manual response condition, we would expect to see a general increase in RTs across the neutral word baseline (2), color related (3), and color word not in the response set (4) conditions as semantic involvement increases. Indeed, this analysis yields a significant linear trend across the three conditions [$F(1,39) = 10.4$, $p < .005$] in the absence of a quadratic trend ($F < 1$). Further comparisons with a Bonferroni correction compared the means from the two *semantic* conditions to the neutral word baseline condition. The 26-msec difference in RTs

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Figure 1. Mean reaction times as a function of response modality and semantic status, as made available by D. Sharma.

between the color related condition and the neutral word baseline condition did not meet the Bonferroni critical difference value of 30.8-msec. In contrast, the 42-msec difference in RTs between the color word not in the response set condition and the neutral word baseline condition exceeded the 32.9-msec Bonferroni critical difference. The results of these analyses are thus consistent with the conclusion that, even when a manual response is used, there is a semantic component to the interference effect in this version of the Stroop task.

This conclusion is buttressed by the results of another line of experiments by McKenna and Sharma (1995).² They reported a series of five Stroop experiments using a *manual* response in which irrelevant threat-related words interfered with color identification relative to neutral words. It is difficult to imagine how threat-related words could produce this effect without having been processed to the semantic level.

CONCLUSION

In response to the question posed in the title of this note, it seems safest, at present, to conclude that the cognitions that press your buttons in these variants of the Stroop task include semantic level processing.

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NOTES

1. It is interesting to note that the amount of Stroop interference produced by nonwords depends on their pronounceability (e.g., *ffq* versus *tuw*, as in Bakan & Alperson, 1967) when color naming is the task. These authors reported more interference when the nonwords were pronounceable than when they were not. Given this finding, it would seem important not to confound orthographic redundancy with lexicality. Pronounceable nonwords are probably a more appropriate nonlexical baseline than the repeating letter strings (e.g., AAAA, BBBB, etc.) used by Sharma and McKenna (1998). It does not stretch the imagination to suppose that pronounceability is more important in the vocal than in the manual response condition.

2. Sharma and McKenna (1998) do not reference McKenna and Sharma (1995).

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