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Stroop Interference and Working Memory - Reply to Stafford on Koch on Stroop-Differences

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Abstract

Koch et al. (1999) presented two studies in which cluster analysis was used to examine individual differences in Stroop processing. Stafford (2000) raised two questions concerning the methodology of Study I and the results from Study II. This reply addresses those issues. It is concluded that cluster analysis can be used examine individual differences but that multiple methods of cluster analysis may be appropriate when analyzing data. Further, the results from Study II are consistent with current research on working memory when comparing across participants. The results, however, do suggest that additional research is needed to determine the role of working memory in tasks involving contradictory pieces of information.

Keywords

cluster analysis, individual differences, short-term memory, Stroop interference, visual reasoning

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I. INTRODUCTION

1. Koch et al. (1999) used cluster analysis as a statistical tool to determine individual differences in Stroop processing. Stafford (2000) has questioned the method of cluster analysis used in the original study and suggested that the findings are contradictory to recent research in the area of working memory. This paper addresses these concerns.

II. CLUSTER ANALYSIS

2. Koch et al. (1999) presented two studies using different versions of the Stroop task to show that participants can be classified into two groups based upon their performance on the tasks. In the first study, integrated Stroop stimuli were presented for varying durations. Although there were differences between the color congruent and color incongruent conditions across durations, performance on the neutral condition varied. Stafford (2000) is correct in noting that interference, obtained by subtracting the neutral and color incongruent RTs, produces inconsistent results and, therefore, may not serve as a useful variable for separating participants into groups based on performance. Unfortunately, choosing a neutral condition for the Stroop task is often difficult since different neutral conditions produce different results (MacLeod, 1991). For this reason, some researchers have examined the Stroop effect by simply comparing the color congruent and color incongruent conditions. In the Koch et al. (1999) study, participants were consistently faster responding to color congruent stimuli compared to color incongruent stimuli. In addition, the

cluster analysis was conducted on the RTs for the conditions and not on the interference scores.

3. In the second study by Koch et al. (1999), a cluster analysis was conducted on scores from Golden's (1978) Stroop Color and Word Test. Again, two groups were found. It was assumed that finding two clusters of participants with two different types of Stroop tasks provided some degree of validity for the procedure. However, it has not yet been determined if participants who cluster into one group on an experimental version of the Stroop task also cluster into a similar group when given a clinical version of the Stroop task or even a different measure of attention or executive processing.

4. Stafford (2000) also noted that a K-means cluster analysis may provide a more appropriate clustering of participants than the hierarchical cluster analysis used by Koch et al. (1999). The choice of clustering method used to analyze the data is an important consideration. Milligan (1981) found that studies comparing the different methods of cluster analysis have sometimes produced contradictory results. This finding has led Aldenderfer & Blashfield (1984) to caution that more research needs to be conducted on the appropriateness of different methods of cluster analysis. With this in mind, Koch & Pritchard (1998) conducted both a hierarchical and K-means cluster analysis when analyzing personality differences on the Stroop task using the NEO-PI-R. No differences were found between the clusters for each method (cf., Lorr & Strack, 1993). Therefore, the hierarchical and iterative methods of cluster analysis may produce similar clusters but it does seem appropriate to employ multiple methods of cluster analysis in order to verify the clusters.

III. WORKING MEMORY AND STROOP INTERFERENCE

III.i. RESULTS FROM KOCH ET AL. (1999)

5. Participants were clustered into two groups in Study II of Koch et al. (1999). Those participants clustered into Group 2 had significantly higher scores on several tests of short-term memory (e.g., matrices, bead memory, and memory for objects) than participants clustered into Group 1. Interestingly, participants in Group 1 exhibited significantly less Stroop interference than those in Group 2. Finding a relationship between attention and memory is not surprising (e.g., Shore & Klein, 2000). However, as Stafford (2000) noted, this finding appears unusual given the assumption that better working memory allows for the inhibition of irrelevant information and appropriate processing of correct information (e.g., Conway & Engle, 1994). Inhibiting irrelevant information and processing correct information would actually result in less interference.

6. A closer examination of the data from Study II of Koch et al. (1999) shows a pattern of results that is not entirely contradictory with recent research on working memory. Overall performance was significantly greater for participants clustered into Group 2 compared to Group 1 (Table 1). Thus, those in Group 2 processed more information across conditions than those in Group 1 but they also demonstrated more interference. The amount of interference is determined by subtracting the mean number of correctly identified colors in the color word panel (Color Naming in Table 1) of the Stroop Color and Word Test (Golden, 1978) from the number of correctly identified colors in the panel of X's. Therefore, comparing across groups, those participants with better working memory (Group 2) demonstrated less interference than those with poorer working memory (Group 1) which is consistent with the prediction that better working memory leads to less interference. However, a within groups comparison shows that participants in Group 2 have more interference than those in Group 1.

TABLE I: Means and standard deviations for Groups 1 and 2 on word

naming, naming the color of X's, naming the color of color words, and Stroop interference. Results from independent sample t-tests comparing the two groups are also presented along with Cohen's D.

	Group 1		Group 2				
	M	SD	M	SD	t	p	d
Word Naming	57.38	9.60	99.00	11.55	15.57	.001	4.34

XXXXX		41.85	8.49	68.44	8.41	12.20	.001	3.13
Color Naming	22.74	6.77	39.33	10.15	7.64	.001	2.45	
Interference	19.12	6.31	29.11	10.01	4.76	.001	1.58	

III.ii. READING ABILITY

7. One factor that may contribute to this pattern of results is reading ability. Although there are significant differences between Groups 1 and 2 across all conditions (i.e., word naming, naming the color of X's, and naming the color print of a color word), the effect size is largest in the word naming condition. This finding suggests that reading ability may play a significant role in Stroop processing. Indeed, theoretical accounts of the Stroop effect are based on the processing supremacy of word information over color information (e.g., LaBerge & Samuals, 1974; Posner & Snyder, 1975). This finding is also consistent with Fournier et al. (1975) who found greater Stroop interference among good versus poor readers. Likewise, developmental studies have shown that Stroop interference is influenced by reading ability (Comalli et al., 1962; Schiller, 1966).

III.iii. MONITORING ABILITY

8. A second factor that may contribute to the pattern of results is monitoring ability. The ability to monitor our responses is a common assumption evidenced in several areas of psychology. For instance, we have the ability to monitor our social behavior (Snyder, 1987), writing (Hayes & Flower, 1980), and motor behavior (cf., Schmidt, 1991). Both humans and primates have been shown to monitor responses (Biro & Matsuzawa, 1999). Further, Shimamura & Jurica (1994) have shown that age related deficits to working memory are associated with impairments in organizing information and monitoring responses. In addition, Schmidt et al. (1990) and Bjork (1988) have suggested that excessive feedback, or monitoring, can be detrimental to performance. Therefore, it may be that in certain situations in which conflicting information is presented, individuals with greater working memory capacity may exhibit more interference due to a higher degree of monitoring their responses compared to individuals with less efficient working memory.

IV. CONCLUSION

9. The results from Koch et al. (1999) suggest that cluster analysis can be used as a tool in examining individual differences in Stroop processing. However, employing multiple methods of cluster analysis to confirm the groups seems appropriate (cf., Stafford, 2000; Lorr & Strack, 1993). In addition, the findings regarding working memory and the Stroop effect indicate that additional research examining the role of working memory in Stroop processing is warranted. To what extent is working memory involved in generating the initial response? Similarly, to what extent is it involved in monitoring and correcting responses? These are important questions which need to be examined.

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