THE EFFECTS OF INCONGRUENT PROBABILITY AND STIMULUS-RESPONSE COMPATIBILITY ON SEQUENTIAL EFFECTS.

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Abstract

Theories of dimensional overlap, translation, and process dissociation were investigated in color naming experiments. Twelve 30 participant groups identified the color of color-word stimuli by touching either a word or a color patch. Incongruent probability varied between groups from 0.25 to 0.86 in six steps. There was significant incongruent inhibition in all conditions, supporting dimensional overlap and process dissociation. Inhibition decreased linearly with increasing incongruent probability, and there was greater inhibition with word than color responding, supporting all three theories. Color naming process remained stable as incongruent proportion increased, but word reading process was reduced, supporting process dissociation. Change in the relevant dimension from the previous trial caused slower congruent RT; irrelevant change slowed incongruent RT. Negative priming had a greater effect on incongruent than congruent RT. Results suggest dimensional overlap, color-color word process dissociation, and priming are the important mechanisms for modeling color-color word responses.

Variation of an irrelevant dimension can inhibit responding to a relevant dimension (c.f. Garner & Felfoldy, 1970). In the current study, stimulus color was the relevant dimension and color words formed the irrelevant dimension; the proportion of incongruent stimuli was also varied. One model of dimensional identification with an irrelevant dimension varying is Kornblum, Hasbroucq, and Osman's (1990) dimensional overlap, stimulus-response (S-R) compatibility model. This model posits two processes that can lead to inhibition: 1) deciding which dimension is relevant for incongruent stimuli and 2) making the response if the irrelevant dimension response entails automatic processing, i.e. speaking. Additionally, stimulus-stimulus (S-S) and S-R compatibility determine whether these processes will produce inhibition. In order to investigate the dimensional overlap model, there were two levels of S-S compatibility: congruent and incongruent stimuli. There were also two levels of S-R compatibility: compatible S-R by touching a color patch and incompatible S-R by touching a word. The S-S and S-R dimensions overlap because they represent the same ideas, albeit in different form. Another model that attempts to explain dimensional overlap results is the translation model (Sugg & McDonald, 1994), based on the idea that one can identify a color either by indicating the color directly by touching a color patch or by translating the color into its name and responding by saying it or touching a word. Inhibition is produced by the translation from one system to another.

In addition to S-S and S-R compatibility effects, others have found effects caused by the relative proportion of congruent and incongruent stimuli. Lindsay and Jacoby (1994) using two levels of incongruent stimuli, found that the level of inhibition in color naming of color word stimuli was reduced as the probability of incongruent stimuli increased. Dimensional overlap and translation models do not predict such an outcome. In the current experiment, the proportion of incongruent stimuli was varied from .25 to .86 in six steps in order to test the linearity of inhibition change.

Another way to consider identification of the color of color words is Lindsay and Jacoby's (1994) two process model. They hypothesize that a colored color word stimulus causes two processes, automatic word reading and controlled color naming, to operate. The two processes occur at the same time, but the word reading process must be at a low enough level before the color naming process can proceed to response. Because the task is color naming, incongruent stimuli, unlike congruent stimuli, produce inhibition by causing the need for a resolution of the word reading-color naming difference. They measure word reading and color naming using accuracy rather than the usual reaction time (RT). Thus, they argue that the probability of a correct response for congruent stimuli is based on the positive effects of both color naming and word reading minus the interaction between the two as shown in Equation 1,

$$p(correct \mid congruent) = Word + Color - (Word \times Color), \quad (1)$$

where Word and Color are the word reading and color naming processes respectively and Word X Color is the interaction between the processes. For incongruent stimuli, there are no positive effects of word reading, thus the probability of a correct response is based on only color naming as a positive aspect and the interaction of word reading and color naming as a negative one as shown in Equation 2,

$$p(correct \mid incongruent) = Color - (Word \times Color). \quad (2)$$

To derive word reading and color naming functions, accuracy of congruent and incongruent stimuli are measured at a series of time limits. They argue that word reading and color naming can be dissociated in this way. They hypothesize that word reading rises and is completed sooner than color naming. Thus, inhibition is the time that word reading inhibits color naming from producing a response. They tested at a small and a large proportion of incongruent stimuli and found that there was little variation in color naming but a large variation in word reading. In the current experiment, the variation in the proportion of incongruent stimuli will test the regularity of change in word reading and lack of change in color naming with increasing probability of incongruent stimuli.

In addition to process dissociation, on can further investigate the sequential effects of the stimulus sequences. Huettel and Lockhead (1999), using two integral dimensions with two levels on each dimension, looked at sequential effects of the previous stimulus on current RT. They found that changing the irrelevant dimension of the current stimulus created more inhibition than changing the relevant dimension. Their explanation was that because one had to suppress the irrelevant dimension in order to respond to the relevant, changing the irrelevant dimension forced one to reprocess the irrelevant dimension and suppress it, while keeping it the same allowed one to continue suppressing that level of the irrelevant dimension. Notebaert, Verbruggen, and Soetens (2005) found similar results with nine color-color word stimuli with arbitrary key press responding. They argue that irrelevant dimensional priming produces increased errors due to negative response priming, rather than response suppression. The current experiment investigates these hypotheses with varying probability of incongruent stimuli and two different response modes.

Method

Twelve groups of 30 students indicated the color of colored word stimuli using a touch screen, half of them by touching a patch of that color and half by touching a word naming that color. The probability of seeing an incongruent stimulus was varied between groups in six steps: .25, .375, .50, .60, .75, and .86. Four colors and words were used: red, yellow, green, and blue. Participants responded to four sets of 48 data collection trials after 12 practice trials.

Results

Mean reaction time (RT) and inhibition were calculated for each participant using the data of the last three sets of trials. The results are shown in Figures 1. The correlation between the proportion of incongruent stimuli and subsequent inhibition in indicating the stimulus color was large for color response (r = 0.939) and for word response (r = 0.995). The results support Lindsay and Jacoby's (1994) hypothesis that inhibition decreases linearly with

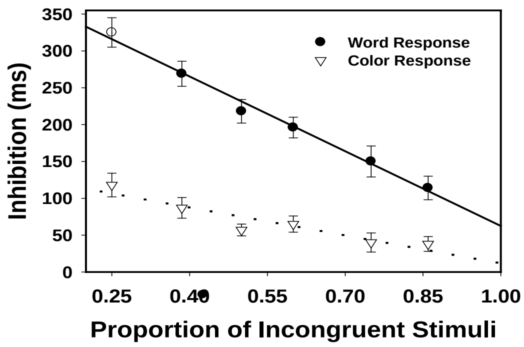

Figure 1. Inhibition as a function of incongruent proportion for word and color responding.

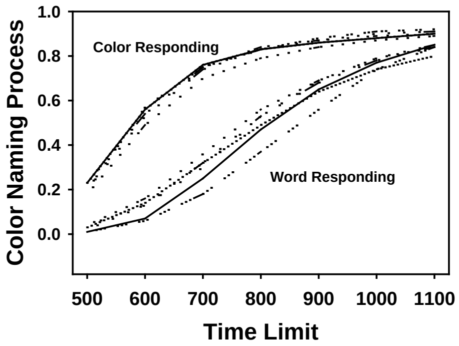

Figure 2: Color naming as a function of the response time limit and incongruent proportion with color and word responding.

increasing proportion of incongruent stimuli. Note that even with color responding, inhibition does not completely disappear with increasing proportion of incongruent stimuli. As expected, word responding produced greater levels of inhibition than color responding, as predicted by both dimensional overlap and translation theories.

The results of Lindsay and Jacoby's word reading – color naming analysis are shown in Figures 2 and 3. As shown in Figure 2, color naming rises more quickly and reaches a higher level with color than with word responding. As shown in Figures 3 and 4, word reading was weaker and less variable with color responding than with word responding.

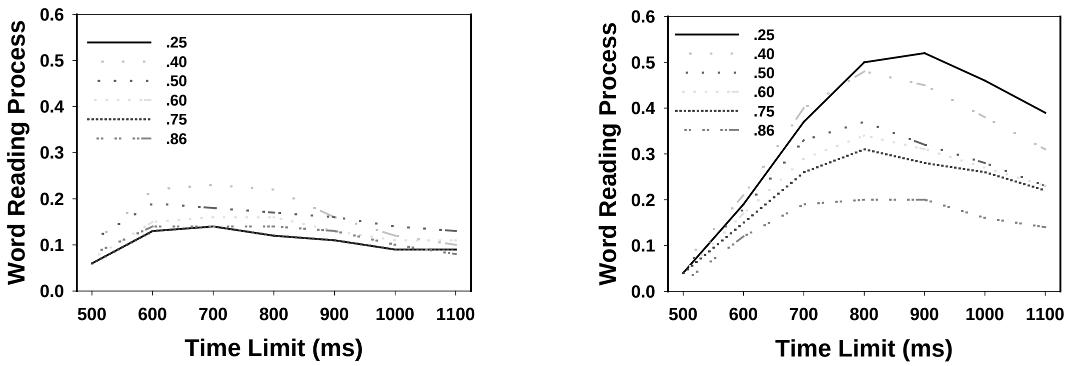

Figure 3: Word reading as a function response time limit and proportion of incongruent stimuli with color responding (A) and with word responding (B).

As predicted, with word responding, color naming varied little with increasing proportion of incongruent stimuli but word reading declined considerably. With color responding, however, there was little variation in either color naming or word reading with increasing proportion of incongruent stimuli. It is as if word reading had been suppressed by the lack of need to respond with a word. Thus, word response results support Lindsay and Jacoby's (1994) process dissociation model, but color response results do not.

The data were further analyzed using an expanded version of Huettel and Lockhead's (1999) approach to sequential analysis. In their data set only four stimuli were presented: two congruent and two incongruent. That data configuration resulted in equal proportions of four sequential effect patterns, each equally probable: no change in either dimension, only the irrelevant dimension changes, only the relevant dimension changes, and both dimensions change. In the current experiment there were four unique congruent stimuli and 12 unique incongruent stimuli. The larger number of stimuli meant that for some proportions of incongruent stimuli, .75 and .86, there were few repeats for congruent stimuli and for most proportions, .25-.75, there were few repeats for incongruent stimuli. Thus the overall analysis used by Huettel and Lockhead would not accurately describe the sequential effects in the current experiments. Notebaert et al. (2005) analyzed congruent and incongruent stimuli separately for sequential effects, using Heuttel and Lockhead's approach. A similar approach was used here.

As shown in Figure 4, change in the relevant dimension disrupted congruent processing with both color and word responding for almost all proportions. There were too few "No Change" stimuli to analyze at proportions of .75 and .86 for both responding modes. Change in the irrelevant dimension caused insignificant disruption for almost all proportions with color responding. With word responding, change in the irrelevant dimension caused less disruption than change in the relevant dimension for all proportions. Thus, change in the relevant, but not irrelevant, dimension appears to cause negative priming for congruent stimuli with both response modes.

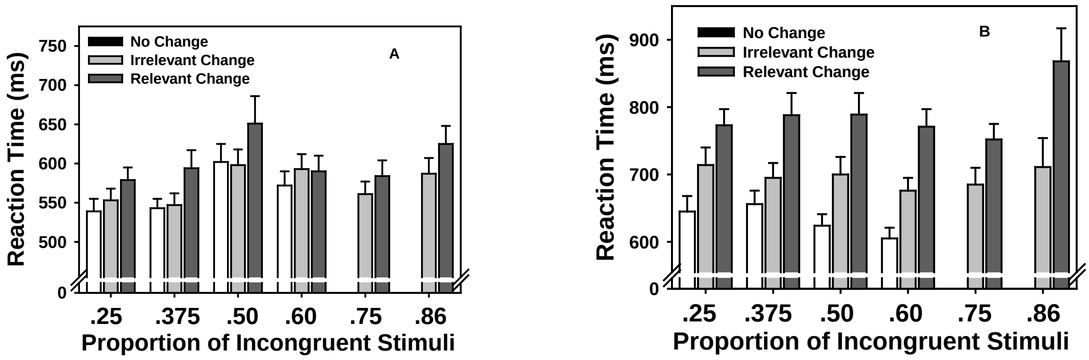

Figure 4: RT to congruent stimuli by the dimensional change of the previous stimulus at each level of incongruent proportion with color responding (A) and word responding (B).

As shown in Figure 5, incongruent stimuli present a different picture of sequential effects. There were too few "No Change" stimuli to analyze except at proportion .86 for both responding modes. For incongruent stimuli irrelevant dimensional change caused greater disruption, either significant or nominal, than relevant change at all proportions for both color and word responding. These results are similar to Notebaert et al.'s (2005). With color responding, there was significant negative priming by the previous relevant dimension when the irrelevant dimension changed, but not when the relevant dimension changed. With word responding, irrelevant change caused greater disruption than relevant change except at a proportion of 0.86. There the opposite held true.

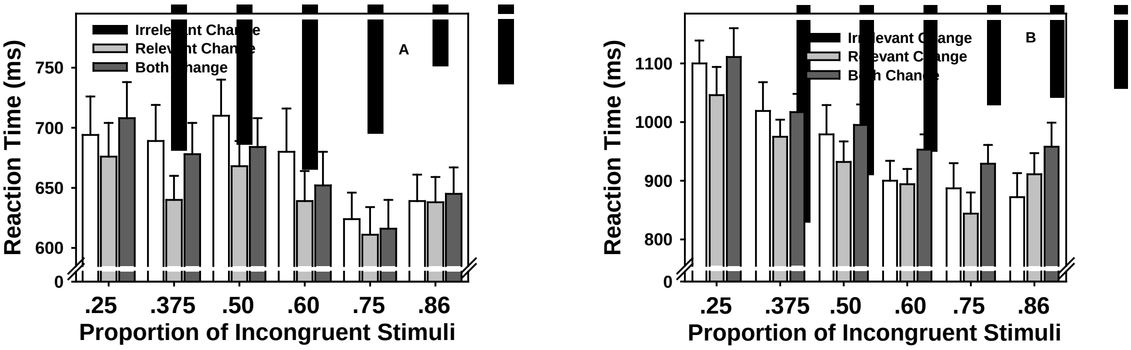

Figure 5: RT to incongruent stimuli by the dimensional change of the previous stimulus dimensional change of the previous stimulus at each level of incongruent proportion with color responding (A) and word responding (B).

Notebaert et al. (2005) calculated weak and strong of negative priming measures. For the weak measure, stimulus n-1 was an incongruent one; stimulus n was either a congruent or incongruent one, the relevant dimension for which matched the irrelevant dimension of stimulus n-1. The comparison stimulus was any stimulus for which the relevant dimension on stimulus n did not match the irrelevant dimension on stimulus n-1. For their strong measure, stimulus n was an incongruent one with the same irrelevant-relevant relations as the weak measure. A similar measure for congruent stimuli was calculated for the current study. For color responding, there was no negative priming

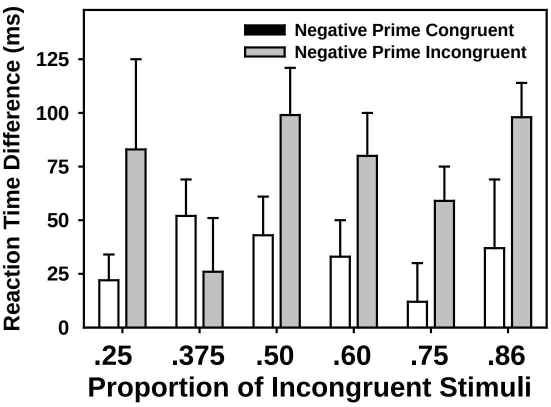

Figure 6: Levels of negative priming at each level of incongruent proportion with word responding using Notebaert et al.'s strong method for incongruent and congruent stimuli.

with either the weak or strong incongruent or congruent measure. Figure 6 shows that for word responding, there was significant or nominal negative priming at all proportions with both the congruent and incongruent stimuli. For all but the .375 proportion, negative priming of incongruent stimuli was much greater than negative priming of congruent stimuli.

Discussion

Although typical inhibition patterns were found with both types of responding, the difference in levels of inhibition, much less for color responding than word responding, indicate an important role for response processes in determining the level of inhibition. Color responding of stimulus reduces the dimensional overlap between the irrelevant dimension and response processes and produces more S-R compatibility than word responding. It also avoids translation from color to word processing, but translation theory predicts no inhibition with color responding. Because there was significant inhibition with color responding, the results seem to support dimensional overlap, S-R compatibility more than translation.

The word responding results also provide support for Lindsay and Jacoby’s (1994) prediction of linearity of inhibition as a function of incongruent probability and for their process dissociation model. Color responding results support the former, not the latter.

The difference in the relative level of disruption caused by change in the relevant dimension compared to the disruption caused by change in the irrelevant dimension for congruent and incongruent stimuli indicates a difference in processing according to stimulus type, a result that fits Lindsay and Jacoby’s (1994) as well as Konblum et al.’s (1990) approach. Presumably, priming with the color of the current stimulus speeds congruent processing and priming with the word of the current stimulus speeds incongruent processing. This phenomenon is unlikely to be a stimulus processing effect; instead it is most likely a response processing effect. Presumably, congruent stimuli are speeded by response priming and incongruent stimuli are speeded by inhibitory priming of the irrelevant dimension, as suggested by Huettel and Lockhead (1999). Negative priming results occurred only with word responding, again indicating the fundamental importance of dimensional overlap and S-R comparibility.

Overall, the results suggest support for theories that emphasize S-R compatibility, process dissociation for word reading and color naming, and priming. Although a number of approaches include some of these ideas, none incorporates all. Such an approach might prove to be the most powerful explanatory theory of the color-color word phenomenon.

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