

THE EFFECTS OF INCONGRUENT PROBABILITY, RESPONSE MODE, AND STIMULUS SET ON RT

John S. Monahan

Department of Psychology, Central Michigan University, Mt. Pleasant, MI 48859

john.monahan@cmich.edu

Abstract

Groups of participants identified the color of color-word stimuli either by typing the first letter of the color name or by saying it out loud. Half the groups saw congruent and incongruent stimuli; the others saw neutral and incongruent stimuli. Incongruent probability varied between groups from 0.25 to 0.86 in six steps. Incongruent inhibition was significant in all conditions but was greater with typing and with congruent stimuli. Inhibition decreased linearly with increasing incongruent probability. Color identification process remained stable as incongruent proportion increased, but word identification process was reduced, partially supporting process dissociation. Neutral RT with typing was usually faster when preceded by a neutral stimulus than an incongruent stimulus about half the time. The preceding stimulus had little effect on incongruent RT. Relevant dimensional changes slowed RT more than irrelevant ones. Results suggest stimulus-response compatibility, color-word process dissociation, and priming are the important mechanisms for modeling 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 varied as well as whether the incongruent stimuli were paired with congruent or neutral stimuli. 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, and two levels of response automaticity, vocal and typing responding.

In addition to S-S compatibility effects, others have found effects caused by the relative proportion of 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 models do not predict that 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 change in inhibition.

Another way to consider identification of the color of color words is Lindsay and Jacoby's (1994) process dissociation model. They hypothesize that a colored color word stimulus causes two processes to operate: automatic word reading and controlled color naming. Because the task is color naming, incongruent stimuli, unlike congruent or neutral stimuli, produce inhibition because of the need for a resolution of the word reading-color naming processes. Lindsay and Jacoby measure word reading and color naming using accuracy rather than reaction time (RT). 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,

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

where Word and Color are the word reading and color naming processes respectively and Word X Color is the interaction between the processes. For neutral stimuli, XXXXX in color, there is no word to facilitate or inhibit the response. The only process affecting neutral processing is color naming as shown in Equation 2.

$$p(\text{correct} \mid \text{neutral}) = \text{Color} \quad (2)$$

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 3,

$$p(\text{correct} \mid \text{incongruent}) = \text{Color} - (\text{Word} \times \text{Color}). \quad (3)$$

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 they tested stimulus sets with 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 with both congruent and incongruent stimulus sets as well as with neutral and incongruent stimulus sets.

Logan and Zbrodoff (1998) found that more inhibition occurred with typing than with vocal responding. The current experiment attempts to replicate and extend their findings. Presumably, dimensional overlap and the process dissociation models will fit results despite changes in responding.

Notebaert and Verguts (2007) found that the sequence of relevant and irrelevant dimensions affects current RT, but that the sequence of the relevant dimension affects RT more than the irrelevant. They also confirmed that the congruency of the previous stimulus affects RT if interstimulus interval (ISI) is sufficient. The current experiment tests these ideas by separate analyses for the sequential effects of congruency, relevant information, and irrelevant information with a relatively large ISI.

Method

Twelve groups of 30 students indicated the color of colored word stimuli by typing the first letter of the color name. Twelve groups of 20 students indicated the color of colored word stimuli by saying the name of the color. Half of the groups saw congruent and incongruent stimuli, and the other half saw neutral and incongruent stimuli. 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. Neutral stimuli were a series of X's. Participants responded to four blocks of 48 data collection trials after 12 practice trials. Only data from the last three blocks were analyzed.

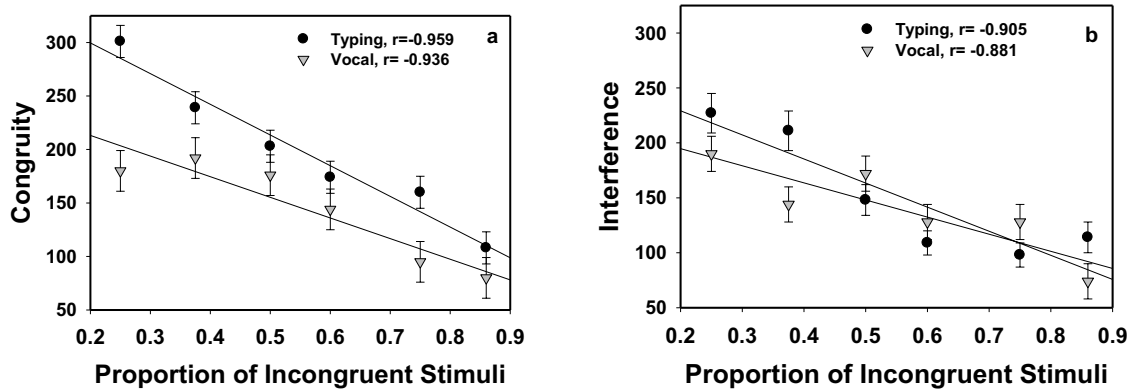


Figure 1. *Congruity (a) as a function of incongruent proportion with typing and vocal responding. Interference (b) as a function of incongruent proportion with typing and vocal responding.*

Results

Mean inhibition, congruity or interference, was calculated for each participant. The results are shown in Figure 1. The correlation between the incongruent proportion and congruity was large for both typing and vocal responding ($r = 0.958$ and 0.936 respectively). The correlations between incongruent proportion and interference were smaller for both response modes ($r = 0.905$ and 0.881 respectively). The results do not fit the dimensional overlap model, but they support Lindsay and Jacoby's (1994) hypothesis that inhibition decreases linearly with increasing proportion of incongruent stimuli. Note that even with high levels of incongruent probability, inhibition does not completely disappear for any stimulus set - response mode combination. As expected from Logan and Zbrodoff (1999), typing produced more congruity than vocal responding.

The results of Lindsay and Jacoby's word reading – color naming analysis and its extension to neutral stimuli are shown in Figure 2. Color naming rose quickly and reached a higher level than word reading in all conditions except neutral and incongruent stimuli with typing responding. Word reading levels were greater with neutral and incongruent stimuli than with congruent and incongruent stimuli.

In three of four instances, color naming varied little with increasing incongruent proportion. Word reading varied significantly with incongruent probability in all cases, but reached higher levels with neutral than with congruent stimuli. Thus, congruent and incongruent results support Lindsay and Jacoby's (1994) process dissociation model, but neutral and incongruent results, as noted by them, offer only weak support.

Notebaert and Verguts's (2007) hypothesis that an immediately prior incongruent stimulus speeds incongruent RT with sufficient ISI was not supported. They found that a 200 ms ISI led to incongruent speeding. According to paired t - tests, the current data show no significant difference between incongruent RT with either an immediately prior incongruent, congruent, or neutral stimulus. Congruent response slowing with an immediately prior incongruent stimulus was found in two of six conditions for vocal responding and one of six for typing. Neutral response slowing was found in four of six conditions for vocal responding and one condition for typing. The results of the analysis are shown in Table 1. Note the reverse nominal and significant effects with more incongruent stimuli.

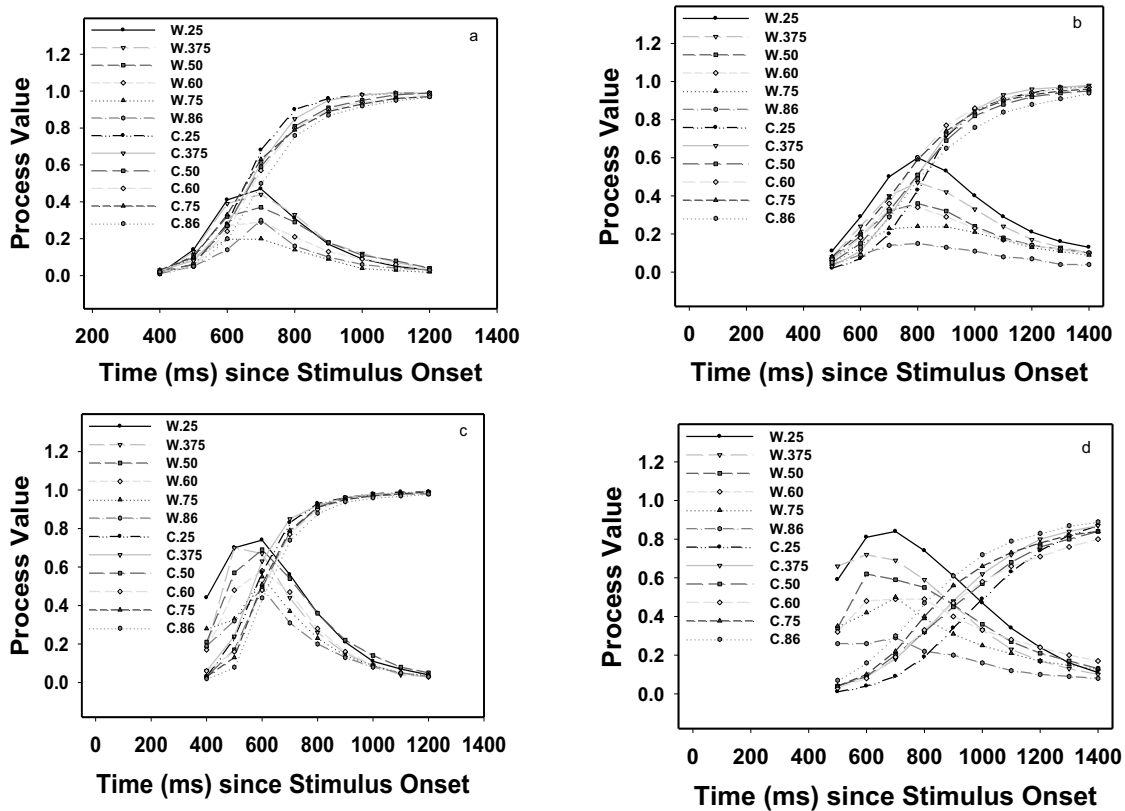


Figure 2. Shows the level of word reading (*W*) and color naming (*C*) with congruent and incongruent stimuli using (a) vocal responding and (b) typing responding and with neutral and incongruent stimuli using (c) vocal responding and (d) typing responding.

The data were further analyzed using a paired comparisons approach rather than Notebaert and Verguts's (2007) regression approach. Notebaert and Verguts used a set of nine stimuli constructed from three colors and their color names. Each stimulus was

Table 1. Congruent and Neutral Slowing and Incongruent Speeding by response Mode and Proportion of Incongruent Stimuli

Condition Tested	Response Mode	Proportion of Incongruent Stimuli					
		.25	.375	.50	.60	.75	.86
Congruent and Incongruent Stimuli							
Congruent Slowing	Vocal	9.8	28.4**	20.0**	9.3	21.7	-29.2*
Congruent Slowing	Typing	11.3*	11.2	5.8	2.2	-29.0*	-25.1
Incongruent Speeding	Vocal	12.4	8.1	-1.5	4.5	1.2	3.3
Incongruent Speeding	Typing	9.7	-7.5	13.8	0.8	-6.3	13.3
Neutral and Incongruent Stimuli							
Neutral Slowing	Vocal	19.7**	19.4*	19.7**	15.8*	3.9	19.7
Neutral Slowing	Typing	25.2*	5.2	6.3	-14.9	-7.7	-37.9
Incongruent Speeding	Vocal	4.8	9.7	1.0	2.9	-1.0	-4.5
Incongruent Speeding	Typing	12.6	2.2	-7.3	-0.8	-8.9	3.8

Note: RT differences in ms. * $p < .05$, ** $p < .01$

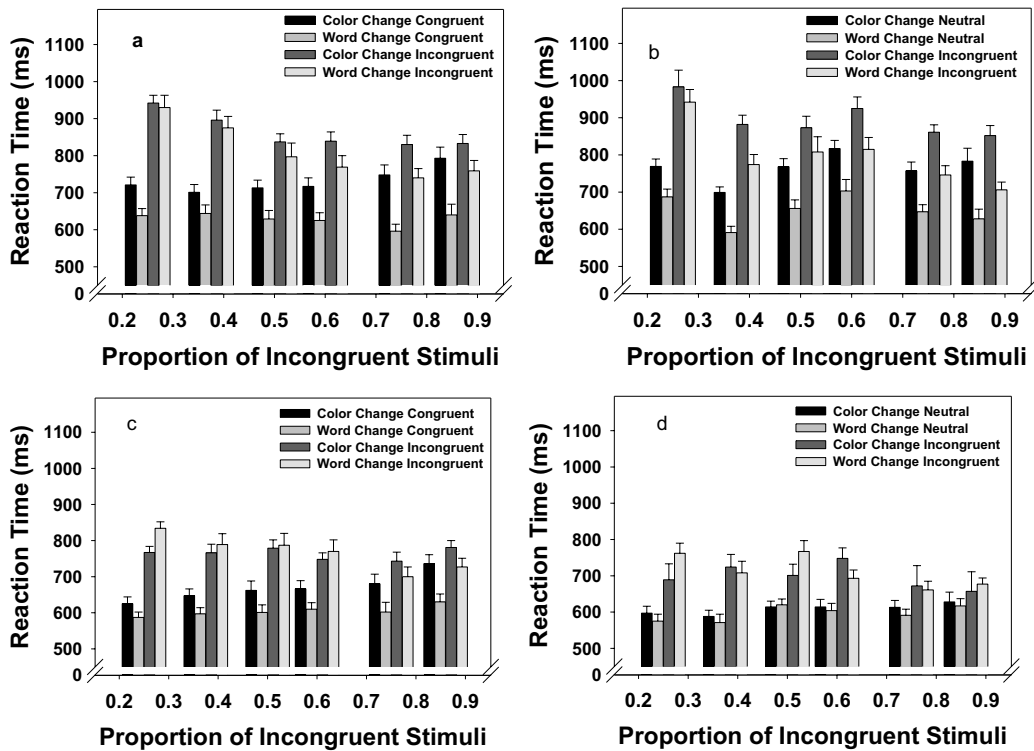


Figure 3: Typing RT for relevant and irrelevant change with congruent and incongruent stimuli (a) and neutral and incongruent stimuli (b). Vocal RT for relevant and irrelevant change with congruent and incongruent stimuli (c) and neutral and incongruent stimuli (d).

presented equally often. Thus incongruent stimuli were presented 67% of the time and congruent stimuli, 33%. In the current experiment there was a set of 16 stimuli constructed from four colors and the colors' names. Equal probability of each stimulus resulted in 75% incongruent and 25% congruent. The current experiment tests their ideas with one greater level of incongruent probability and four lesser levels. Typing ISI was about 1400 ms. Vocal ISI was at least 900 ms, with variability caused by the experimenter translating the vocal utterance into a key press.

As shown in Figure 3, with both vocal and typing responding, change in the relevant dimension disrupted congruent processing more than change in the irrelevant dimension for all incongruent proportions but disrupted incongruent processing only at higher proportions. With typing responding, change in the relevant dimension disrupted more than change in the irrelevant dimension for all proportions with neutral and incongruent stimuli. With vocal responding, change in the relevant dimension did not disrupt more than change in the irrelevant dimension for all proportions with neutral stimuli and all but one proportion for incongruent stimuli.

Discussion

Logan and Zbrodoff's (1998) finding that typing produces greater Stroop congruity than vocal responding was replicated for congruent and incongruent combinations, but not neutral and incongruent combinations. For the latter, the lack of effect of the difference in response methods points to a particular role for congruent stimuli, both increasing inhibition and differentiating between response modes. Presumably, greater automaticity with vocal responding led to less inhibition.

Lindsay and Jacoby's (1994) process dissociation approach seems to show that the difference between typing and vocal responding is related to both word reading and color naming. Word reading scores have a much greater peak with typing than with vocal responding for congruent and incongruent stimuli. With neutral and incongruent stimuli, word reading was about the same, but color naming was much lower with typing than with vocal responding. Overall, typing and vocal responding seem to incite different processes for response production.

Notebaert and Verguts's (2007) notion that congruency of the prior stimulus has an effect on current RT was only partially supported. Incongruent speeding did not occur despite a relatively long ISI. Congruent slowing occurred in a minority of conditions. Only neutral slowing, not part of Notebaert and Verguts's hypothesis, and only with vocal responding, occurred in a majority of conditions. It would appear that incongruent speeding and congruent slowing are affected by ISI, too small or too large reduces the effect, the proportion of incongruent stimuli, greater effect with fewer incongruent stimuli, and the stimulus type affected, incongruent speeding seems less robust than congruent slowing.

Notebaert and Verguts's (2007) other notion, that change in the relevant dimension has a greater effect on RT than change in the irrelevant dimension received only partial support. Typing responding yielded significant or nominal effects in the right direction for all incongruent proportions with both stimulus combinations. Vocal responding yielded significant positive effects for congruent and incongruent stimuli for congruent change, but not for incongruent change below an incongruent proportion below 75%. Vocal responding with neutral and incongruent stimuli yielded only one significant effect, at an incongruent proportion of .60 incongruent relevant change was greater than irrelevant change.

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.

References

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