Psicothema
2000. Vol. 12, Supl. nº 2, pp. 60-63

ISSN 0214 - 9915 CODEN PSOTEG

Effects of Type of Design (Blocked *vs.* Randomized) on Stroop and Emotional Stroop Tasks

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The purpose of the present study was to investigate the effects of stimulus fragmentation on Stroop and emotional Stroop interference and facilitation effects when stimuli at all fragmentation levels were blocked by condition as well as when they were totally randomized across conditions. Under blocked conditions, in which stimuli from the same condition (e.g., congruent, incongruent, control conditions) at all levels of fragmentation were presented in the same block, interference appeared even at the most fragmented level, and increased linearly until level 8. The same occurred with facilitation. Randomized designs, on the other hand, showed that interference did no appear until level 4 and increased linearly until level 8, whereas facilitation disappeared. Previous work from our laboratory showed that words are objectively identified at level 4. The findings suggest the existence of a response set in blocked designs, which in turn may speak against the automaticity of the Stroop effect.

Efectos del tipo de diseño (bloqueado vs. aleatorizado) en la tarea Stroop y Stroop emocional. En una serie de experimentos estudiamos el efecto de la cantidad de información estimular en el efecto Stroop y Stroop emocional, manipulando la presentación de palabras presentadas a ocho niveles de fragmentación diferentes. Además, una segunda variable fue el tipo de diseño. En diseños bloqueados todos los ensayos pertenecientes a la misma condición experimental (v.g., congruente, incongruente, neutral, etc.) se presentaban en el mismo bloque de forma aleatoria a todos los niveles de fragmentación. Por el contrario, en el diseño aleatorizado, los ensayos aparecían totalmente al azar. Los resultados mostraron que con el diseño bloqueado, la interferencia y la facilitación Stroop aparecían incluso en niveles de compleción en los que la palabra, objetivamente, no podía identificarse. Estos resultados sugieren la existencia de una disposición de respuesta en el observador. La repetición de palabras pertenecientes a una misma condición a distintos niveles de compleción (algunos no identificables y otros sí) podría dar lugar a la disposición de respuesta. Los resultados del diseño aleatorizado, en el que no se creaban expectativas sobre la condición del estímulo, mostraron que el efecto Stroop aparecía sólo a partir del nivel 4, nivel en el que objetivamente se identifica la palabra en tareas de identificación. Estos resultados no son consistentes con la automaticidad del efecto Stroop.

William James (1890) most quoted sentence is perhaps that «Everyone knows what attention is». However, as Styles (1997) recently has remarked, attention is a concept that psychologists have been hesitant to define. The point is that not all psychologists agree what it should be understand by attention. There are different types of attention as there are also many varieties of memories. Attention and memory are psychological processes that appear intimately related.

Selective attention enables the processing of relevant stimuli, while suppressing other irrelevant stimuli that may appear at the visual field. However, a large number of studies have shown that selective attention is not totally successful because human observers cannot always ignore irrelevant information (Ballesteros & Manga, 1996).

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There is no doubt that attention during encoding has a profound influence on explicit memory measured by recall and recognition tests. In contrast, the influence of attention on implicit memory assessed by repetition priming tests is a debated issue. A number of recent studies have shown that divided attention at encoding has little or non-effect on perceptual implicit tests while strongly affects performance on explicit memory tests (e.g., Eich, 1984; Mulligan, 1998; Parkin & Russo, 1990; Szymansky & MacLeod, 1996). However, these studies do not demonstrate implicit memory without attention because the participants were instructed to attend to all the stimuli. Very recent work on selective (focused) attention suggest that some level of attentional processing is necessary to support perceptual implicit memory for words (Bentin, Moscovitch, & Nirhod, 1998; Crabb & Dark, 1999; MacDonald & MacLeod, 1998; Wood, Stadler, & Cowan, 1997) as well as for pictures (Ballesteros & Reales, 1998a; Ballesteros, Reales, Carrasco, & García, submitted). A recent word study has shown that when attention was controlled more effectively using a blocked design, repetition priming was found only for attended words. However, in a mixed condition that made difficult to allocate atten-

tion selectively, equivalent repetition priming was found for both attended and unattended words (Bentin et al., 1998). In blocked conditions, the observer was presented with two words: One printed in red and other in blue, knowing in advance which color should be attended. So, in this condition it was easy to allocate attention to those words that appeared in the designed color. Possibly these words captured almost all the attentional resources. On the mixed condition, however, the attended color was randomly determined in each trial. The conclusion from the above findings suggests that a minimal amount of attention at encoding is necessary to build a long-lasting representation that can support repetition priming.

The above discussion is relevant to the subject of the present paper. That is, how the experimental design (blocked across conditions versus totally randomized) can influence on processing of compound stimuli that vary in two dimensions: color and word?

One of the most widely studied tasks in cognitive psychology is the Stroop task (Stroop, 1935). Stroop's (1935) celebrated paper deals with attention and interference and this work is more influential nowadays than it was at the time it was published. According to MacLeod (1991), the Stroop task still fascinates researchers on attention because it is seen as tapping in to very primitive operations of cognition. Moreover, the Stroop effect is a very robust phenomenon, easy to replicate in laboratory and clinical settings.

Stroop (1935) showed that subjets' ability to name the ink color in which an incongruent «color-word» is printed is inhibited compared to their ability to name the ink color of a nonword color patch. However, the incongruent color ink does not inhibit reading the color-word. For example, observer's ability to name the color of blue ink in which the word RED is printed would be inhibited. However, under the same conditions, observer's ability to read the word GREEN printed in red ink would be unaffected.

Today, numerous variations of the Stroop task, called Stroop-like tasks, have confirmed this Stroop asymmetry and the extent of the effect has prompted extensive inquire. Researchers have proposed several theories based on automaticity, response-compatibility, and relative speed of processing to account for the *Stroop interference effect*. However, theorists are still striving to explain the effect as none o them are able to account for all the empirical findings.

The Stroop effect is a clear example showing that unattended stimulus dimensions are processed, at least, to a certain extent. Many studies have shown the interfering nature of irrelevant stimulus features on responses to target dimensions. The *Stroop interference effect* is the increase in reaction time in responding to incongruent trials in comparison with neutral trials (e.g., Dyer, 1973; MacLeod & Dunbar, 1988; Stroop, 1935). The effects obtained in the Stroop task are a good example of people's selective attention and the capacity of certain stimuli to escape attentional control. In the Stroop paradigm, participants are asked to respond to stimuli that vary in two dimensions, one of which they are asked to ignore. The Stroop effect shows that unattended stimulus dimensions are processed at least to a certain extent.

The word-fragmentation-level as a new variable to study selective attention

Many low-level behaviors such as eye-blink or other reflexes are automatic because they occur without intention. It has been argued that some well-learnt tasks, like reading, are also automatic in the sense that well trained reader's process irrelevant words unconsciously without intent. Therefore, reading the word is said to be automatic in the sense that skilled readers cannot refrain from extracting the meaning. Even though task instructions explicitly ask participants to say the color in which the words were written and not to attend to the meaning of the word, they are unable to do so (e.g., Rayner & Pollatsek, 1989; Reisberg, 1997). Some recent findings, however, suggest that a large amount of semantic processing is controlled locally by elements of the task (Besner & Stolz, 1999; Besner, Stolz, & Boutler, 1997). These results are consistent with the idea that mental set is critical to performance on the Stroop task.

We have put forward a mental set interpretation to account for a number of results from our laboratory showing the influence of observers´s expectations on Stroop interference and facilitation. More explicitly, when words at different fragmentation levels (see below) were presented blocked across experimental conditions, a response set was observed. A large Stroop interference and also facilitation appeared at all fragmentation levels. However, a randomized (mixed) stimulus presentation showed that Stroop interference appeared at fragmentation level 4, and increased linearly until level 8. Fragmentation level 4 is precisely the level at which objectively words started to be readable.

Method

In a series of experiments we have investigated the effect of word-fragmentation-level on Stroop interference and facilitation in the Stroop (Ballesteros, Reales, & Manga, 1999) and the emotional Stroop tasks (Ballesteros & Reales, 1998b). The strategy of these experiments was to vary the amount of irrelevant stimulus information present in the color-word stimulus compound and see how this stimulus variable influenced in incongruent, congruent and control stimulus conditions to evaluate this variable in color naming. Twenty young adult observers participated in each experiment.

Color-word stimuli were fragmented at 8 different levels using the Snodgrass and Poster´s (1992) algorithm. Each color-word was stored as fragmented stimuli at 8 different levels of completion from level 1 (the most fragmented stimulus condition) to level 8, which corresponded to the complete color-word. Figure 1 shows some examples corresponding to the vertical trials at the 8 fragmentation levels. Examples shown in Figure 1 correspond to some of the experimental conditions manipulated in the experiments: the Congruent condition, the Incongruent condition and the Orthographic condition. The stimuli were upper-case four to five letter words presented vertical or horizontally for 144 ms at the center of the screen of a 486 PC (640 x 480 pixels resolution) in color red, blue or green. The computer was interfaced with a Lafayette 63040 vocal key to record reaction time, which was measured from the presentation of the word on the screen to the vocal response. The task was to name the color of the words as soon as possible while trying no to make errors. The experimenter recorded false-triggered responses and errors, which were very small. Five experimental conditions were varied across the experiments on the Stroop paradigm but we will concentrate here only in the incongruent, congruent and control conditions. In the incongruent condition, color words appeared at a different color (i.e., BLUE in red, RED in green, GREEN in blue). In the congruent condition words and colors matched (i.e., RED in red, BLUE in blue, GREEN in green). Finally, in the control condition a series of consonant letters were shown (e.g., RXTX in blue, VXNDT in red, XZXR in green).

In experiments on the emotional Stroop task paradigm, additional to the usual congruent, incongruent and control conditions, emotional negative (e.g., CANCER in blue, DEATH in green) and positive words (e.g., LOVE in red, HOUSE in green) were also included as experimental conditions. We tested several predictions: if only emotional negative but not emotional positive words produce a cost, interterference should be found for negative but not for positive words. On the other hand, if both type of words interrupt the processing it should be observed interference for negative as well as for positive words. Finally, an increase in the interference for emotional words (either positive o negative words) as word-fragmentation-level increases making easier to read the word would favor the semantic hypothesis. That is, as more and more information is accruing about the word presented at the screen, interference and facilitation would increase.

Results

We refer here just to two crucial results: The effect of stimulus fragmentation and the effect of type of design on Stroop and emotional Stroop interference and facilitation effects. In these experiments latency was the main variable. The mean number of errors was lower than 1% and was equally distributed across experimental conditions. In blocked experimental designs, the expected Stroop interference and facilitation effects were found ($p < .001$). Incongruent color-words (mean 750 ms) were processed slower than control stimuli (mean 650 ms) while congruent color-words (mean 560 ms) were processed faster than control words (all ps < .01). The variable level of fragmentation was not significant as a main effect but the interaction condition x fragmentation level was significant ($p < .001$). Level of fragmentation did not influence the neutral condition but it did the other conditions. However, interference and facilitation were obtained even at fragmentation levels at which words were not readable (fragmentation levels 1 to 3). Moreover, interference showed a linear trend and was the largest at fragmentation level 8.

Similar results were found in the emotional Stroop task using as well a blocked design. Condition was highly significant as a main effect ($p < .001$). Incongruent trials were slower than all the other conditions (congruent, neutral, positive emotional and negative emotional). Again, fragmentation level was not significant but it was the interaction between the two variables ($p < .001$). Positive as well as negative emotional words showed equal amount of interference. The linear trend suggests that as the possibility to capture the emotional meaning increases so do interference. It seems that emotional words capture attention independently of its positive or negative valence. However, even at fragmentation level 2 at which is nearly impossible to read the word, interference was about 85 ms. For negative and positive words a 20 ms interference was found at fragmentation level 2 and increased to nearly 60 ms at fragmentation level 8 (the complete word).

When in another experiment a randomized experimental design was used in which stimuli were mixed across experimental conditions and fragmentation levels both variables, condition and fragmentation level were significant ($p < .001$). The interaction between these two variables was also significant ($p < .001$). There was not interference until level 4 (about 60 ms). Previous results from our laboratory showed that level 4 is the level at which objectively the word was identified. Stroop interference increased linearly from level 4 to level 8 (150 ms) while Stroop facilitation was not significant.

Conclusions

In a series of experiments we investigated the influence of stimulus fragmentation in interference and facilitation on Stroop and

Figura 1. *Examples of words used in the Stroop experiments showing the eight fragmentation levels from level 1, the most incomplete, to level 8 the complete word. In the first row are shown congruent stimuli, in the middle row control stimuli, and at the bottom row incongruent stimuli*

Stroop-like tasks. This manipulation allowed us to study the way in which quantity of stimulus information influenced interference and/or facilitation on selective attention tasks. Moreover, the manipulation of experimental design (blocked versus randomized) allowed us to investigate whether or not exist a response set. The rationale was that when all trials corresponding to the same experimental condition (e.g., incongruent condition) are presented in the same block at different fragmented levels, observers will be predisposed to respond in a certain way to stimuli that might appear at a very fragmented level. Our results suggest that the response set produced interference, even at fragmentation levels at which objectively it was impossible to capture the word semantic information. In contrast, when stimuli at all fragmentation levels were randomized across experimental conditions, the response set disappeared. Interference started to be significant only at fragmentation level 4 and increased linearly until level 8 (the complete word). The findings showed the importance of how different trials are presented to observers. The manipulation of the experimental design allows to predicting when response set will appear. In presentations blocked by condition, observers implemented a mental set that made responses slower at congruent or faster at incongruent conditions.

Our findings suggest that a mental set rise by stimulus expectation is responsible for large amounts of interference and facilitation under blocked conditions. Congruent and incongruent conditions create a contextual effect in which more readable words influence expectations for less readable words. As a result, interference and facilitation appeared when responding to stimuli that objectively are not seen. When expectations are aborted, interference showed only when stimulus semantic information is enough to make words readable. Moreover, interference increases linearly until the presentation of the complete word. Note that precisely this is the usual way of showing color-words in hundreds of experiments using the Stroop paradigm.

Finally, it is important to specify the conditions under which a response set influence performance because the differential effects of expectations on attention are against theories of the Stroop effect based on automaticity. Moreover, as pointed out in the Introduction, blocked *versus* mixed study conditions influence the role of attention on implicit memory. The finding that in blocked study conditions in which control of attention is more rigorous, memory is only found for attended stimuli may serve to resolve inconsistencies in the relationship between attention and memory literature. Contrary to the idea that automatic sensory processing without attention deployment to the stimuli is enough for implicit but not for explicit memory, recent findings may resolve inconsistencies in the attention/memory literature. These findings suggest that implicit memory as Stroop interference is not totally automatic.

Acknowledgment

This research was supported in part by DGICYT Project PB-94-393.

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