Stroop Effect induced by Semantics in Chinese Idioms with Color Words

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Abstract. We explored the role of a color word and color meaning in an idiom played in the Stroop effect. With a print color-naming task, our results revealed that the color word played an important role in the Stroop effect. A color word could induce a strong Stroop effect no matter with or without color meaning in an idiom. In the congruent condition, an idiom with both a color word and color meaning could be processed faster than the one without a color word in a congruent condition. While in an incongruent condition, with both a color word and color meaning, the processing of the print color was delayed in comparison with the idiom with only the color meaning. In our control experiment, we applied three conditions with a key press task to dissociate the semantic competition and response competition effects in the Stroop task. The processing of stimulus-stimulus compatible trials for idioms with a color word was faster than the stimulus-stimulus incompatible trials for idioms with a color word. This indicates that semantics play a role in target processing.

Keywords: color-naming task, Stroop effect, semantic competition, response competition.

1. Introduction

The Stroop effect is named after John Ridley Stroop, who first published the effect in English in 1935[1]. After decades of research on the Stroop effect, many behavioral tasks have been developed including the classic color-word task [2], Day-Night Stroop task [3], Bilingual Stroop task [3], reverse Stroop task [3], and emotion Stroop task [3]. The Stroop effect is generally describing the delay in response time between the congruent and incongruent stimuli. The stimuli in Stroop paradigms constituted 3 groups: neutral, congruent, and incongruent. In the color-word task, the print color is the target dimension (required to be reported) and the word that itself typically spells out a color word is the distractor dimension. The neutral stimuli are those symbols with print color (e.g., "##" in green). The congruent stimuli are color words whose meaning matched the same print color (e.g., the word "green" displayed in green, $GREEN_{green}$). The incongruent stimuli are the word displayed in a different color from the meaning of the word (e.g., the word "green" in blue, $GREEN_{blue}$). When asked to name the color of the word it takes longer and is more prone to errors when the color of the print does not match the name of the color.

Semantic activation in the Stroop task is automatic. Semantic interference was found when naming the print color of the neutral stimuli is faster than in incongruent conditions (e.g., $GREEN_{blue}$). At the same time, semantic facilitation reveals that naming the print color of the congruent stimuli is faster (e.g., $GREEN_{green}$) than when neutral stimuli were displayed. However, when the task required reading the word, both semantic interference and semantic facilitation disappeared.

The Stroop effect is mainly explained as theories of processing speed, selective attention, automaticity, and parallel distributed processing. The processing speed theory suggests that there is a lag in the brain's ability to recognize the color of the word due to faster reading the words than processing color. If the task is to report the color, the semantic information comes to the decision-making stage before the color information, which produces processing conflict. On the other hand, if the task is to report the word since the color information lags after semantic information, a decision can be made before the confliction information. The selective attention theory proposes that color recognition, compared with reading a word demands more attention. The Stroop effect may be a result of either a distribution of attention to different responses or greater inhibition of distractors. The

automaticity theory is the most common explanation of the Stroop effect. Stirling (1979) introduced the concept of response automaticity. He demonstrated that changing the responses from colored words to letters that were not part of the colored words increased reaction time while reducing Stroop interference. Habitual reading leads to automatic semantic processing that does not need controlled attention but still uses enough attentional resources resulting in a reduction of the attention needed for color processing. Parallel distributed processing suggests that different and specific pathways are developed for different information analyses. When two pathways are activated in the Stroop effect at the same time, interference happens between the stronger pathway (semantic processing) and the weaker pathway (color naming), especially when the response relies on the weaker pathway.

In our experiments, we used the Chinese idioms which consist of four characters to explore the role that the color character and color meaning played in a Stroop effect. We were able to investigate the Stroop effect from three dimensions, which were color, character, and meaning. We try to examine different patterns of response competition between color and meaning, as well as color and character.

2. Methods

2.1 Experiment 1 Oral report of print color task

2.1.1 Participants

A total of 16 participants took part in the experiment, 9 male and 7 female with an average age of 21. They were all native Mandarin Chinese speakers, had a normal or corrected-to-normal vision, and were not color-blind. They all signed consent forms and paid for their time and effort.

2.1.2 Apparatus

Participants sat 60 cm away from the screen and viewed the stimuli being presented on a laptop. The monitor was 34.5 cm in width and 19.5 cm in height with a resolution of 1920*1080 and 60 Hz refresh rate.

2.1.3 Stimuli

The stimuli were displayed using PsychoPy3. The stimulus was displayed in the center of the screen with a gray background. Letter x was used as the baseline condition. We chose eight idioms in each of the four conditions, including idioms with the meaning of colors and with color words (e.g. Cha Zi Yan Hong), idioms with color words but without the meaning of colors (e.g. Xiao Jia Bi Yu), idioms with the meaning of colors but without color words (e.g. Hai Tian Yi Se), as well as idioms with either meaning of color or color words (e.g. San Cong Si De). All the idioms were in Chinese Song font with a size of 6 degrees. We adopted four kinds of colors (red, green, black, blue).

Table 1. Including idioms with the meaning of colors and with color words

Idioms with color words and describe colors yWyM	Idioms with color words but without meaning of colors yWnM	Idioms without color words but with the meaning of colors nWyM	Idioms without color words nor meaning of colors nWnM
Mian Huang Ji Shou （Huang）	Qing Mei Zhu Ma （Lan）	Yu Yu Cong Cong （Lv）	Le Ji Sheng Bei
Jie Bai Wu Xia（Bai）	Ping Bai Wu Gu （Bai）	Xue Liu Cheng He （Hong）	San Xin Er Yi
Cha Zi Yan Hong （Hong）	Liu Ming Qing Shi （Lan）	Chi Ao Feng Ju（Huang）	Zi Yi Wei Shi
Lv Cao Ru Yin （Lv）	Bu Fen Zao Bai （Bai）	Bing Tian Xue Di （Bai）	Yu Zhong Xin Chang
Hong Hong Huo Huo （Hong）	Xiao Jia Bi Yu （Lv）	Hai Tian Yi Se （Lan）	Mu Zhong Wu Ren
Yue Bai Feng Qing （Bai）	Xin Kou Ci Huang （Huang）	Liang Bin Ran Shuang （Bai）	She Ji Wei Ren
Yi Bi Qian Li （Lv）	Hong Yan Zhi Ji （Hong）	Nu Huo Chong Tian （Hong）	Qiu Zhi Bu De
Qing Chu Yu Lan （Lan）	Fei Huang Teng Da （Huang）	Ye Luo Gui Qiu （Huang）	Xiao Ti Da Zuo

2.1.4 Procedure

We adopted the classic Stroop effect paradigm. The participants were required to orally name the print color of the idioms presented on the screen. They were instructed to ignore the related color meaning if the idioms had. The participants' responses were recorded via X microphone headset and recorded on the laptop. Voice recording started synchronized with the item onset and ended after participants' responses. The participants start the experiment after pressing the space key on the keyboard.

The four kinds of stimuli and the baseline condition were presented randomly. The stimulus was present for 3 s at most, and the stimulus disappeared after the subjects responded (Fig.1).

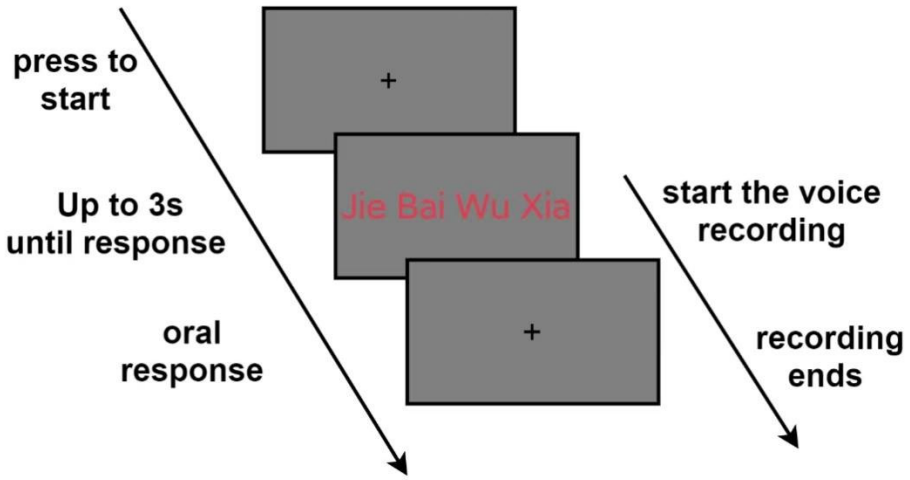

Fig.1 Trial structure of experiment

2.1.5 Results

The response time of the four kinds of stimuli (with both color words and color meaning (yWyM), without either a color word or color meaning (nYnM), with color word and without color meaning (yWnM), as well as without a color word and with color meaning(nWyM)) minus the baseline response time was used to quantify the subject's response to different idioms. A 2*2 (color word yes or no * color meaning yes or no) ANOVA analysis was conducted to measure the Stroop effect of this experiment. The main effect of color word factor was significant ($F_{(1,14)} = 4.75$, $p<0.05$, $\eta^2=0.05$). The main effect of color meaning and interaction of these two factors were not significant (Figure 1). We further analyze the congruent or incongruent conditions of each kind of stimuli. The results indicated that the idioms with both color word and the color meaning could induce a strong Stroop effect ($yWyM_{con}$ vs. nWnM, $t_{(14)} = 7.45$, $p<0.001$, Cohen's d = 1.92; $yWyM_{incon}$ vs. nWnM, $t_{(14)} = -3.07$, $p=0.008$, Cohen's d = -0.79). If the color meaning is absent, the facilitation effect was absent while the interference remained (nWnM vs. $yWnM_{incon}$, $t_{(14)} = -4.07$, $p<0.001$, Cohen's d = -1.05). In the congruent condition, an idiom with both color word and color meaning could facilitate the processing of the print color of this idiom ($yWyM_{con}$ vs. $nWyM_{con}$, $t_{(14)} = -5.13$, $p<0.001$, Cohen's d = -1.32; $yWyM_{con}$ vs. $yWnM_{con}$, $t_{(14)} = -3.89$, $p=0.002$, Cohen's d = -1.01). With a color word printed in an incongruent color, the processing of the print color of this idiom was significantly compromised compared with the idioms without a color word but with color meaning in incongruent conditions ($yWyM_{incon}$ vs. $nWyM_{incon}$, $t_{(14)} = 3.48$, $p<0.004$, Cohen's d = 0.90; $yWnM_{incon}$ vs. $nWyM_{incon}$, $t_{(14)} = 3.06$, $p=0.009$, Cohen's d = 0.79). We also observed the interference caused by the color word in the idioms without color meaning (yWnM vs. nWnM, $t_{(14)} = 2.20$, $p<0.05$, Cohen's d = 0.57). Moreover, the print color of idioms with a color word and color meaning were processed more quickly than the

idioms with a color word and no color meaning (yWyM vs. yWnM, $t_{(14)} = -2.10$, $p<0.05$, Cohen's d = -0.57).

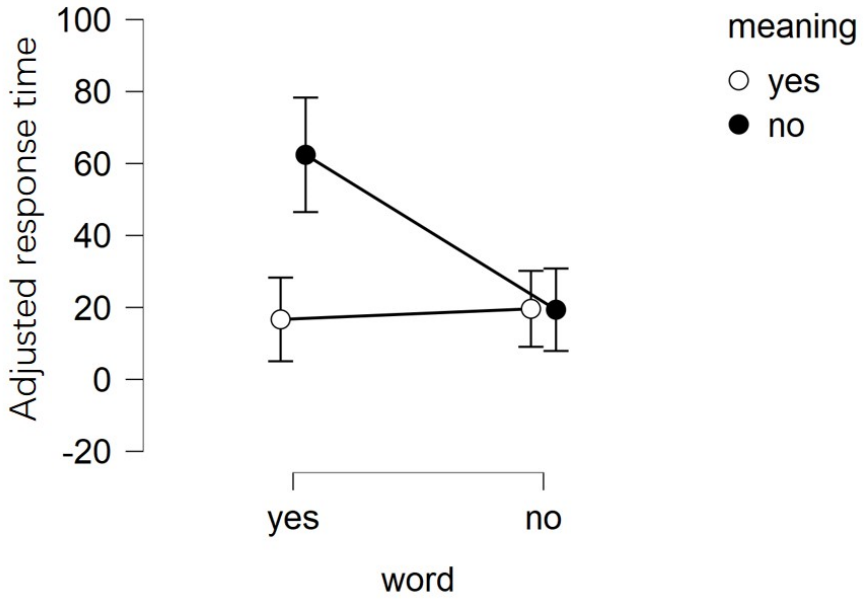

Fig.2 Results of experiment

2.2 Experiment 2 Manual Stroop task

The previous experiment showed that a color word could affect the processing of the idioms and induce a Stroop effect. Here we employed a manual Stroop task to dissociate semantic and response competition effects between color and word processing. We used three types of trials. Identity trials were both semantically compatible and response compatible (e.g. Mian Huang Ji Shou, in yellow), different response trials were both semantically incompatible and response incompatible (e.g. Mian Huang Ji Shou, in green), and same response trial were semantically incompatible and response compatible (e.g. Mian Huang Ji Shou in white, here both the yellow and white color were responded with the same key).

2.2.1 Participants

A total of 32 participants took part in the experiment, 17 male and 15 female with an average age of 24. They were all native Mandarin Chinese speakers, had normal or corrected-to-normal vision, and were not color-blind. They all signed consent forms and paid for their time and effort.

2.2.2 Apparatus & stimuli

The apparatus and stimuli were the same as that in experiment 1.

2.2.3 Procedure

We used three types of idioms, which were, yWyM, idioms with both color word and color meaning, yWnM, idioms with a color word and without color meaning, and nWyM, idioms without a color word and with color meaning. The colors of the words were yellow, white, red, and green. The participants were required to recognize the print color of the words by pressing the left arrow and right arrow keys. The colors yellow and white were responded in the same key, while the colors red and green were responded in the other key. Twenty or more practice trials proceeded first in order to assure the participants got used to the same key response.

2.2.4 Results

For all the idioms, the response times between the three different types of trials were not significant (P>0.1). However, we observed that for the idioms with a color word, the response time of identity

trials was significantly smaller than the response time of the same trials ($t_{(31)} = -1.93$, $p<0.03$, Cohen's $d = -0.34$).

3. Discussion

Our research revealed that the color word rather than the color meaning in the idioms played important role in the Stroop effect. An idiom with both a color word and a color meaning could induce a strong Stroop effect. In the congruent condition, an idiom with a color word could facilitate the processing if it had a color meaning. However, in an incongruent condition, the processing of idioms with a color word could more easily be disturbed. In the print color-naming task, a color word was processed more quickly than the color meaning. The faster processing of stimulus-stimulus-compatible trials over stimulus-stimulus incompatible trials indicates that the semantic competition plays a role in target processing.

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