# Neuropsychological decomposing Stroop interference into different cognitive monitoring: an exploratory factor analysis

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## Abstract

**Introduction:** There are two alternative explanations of Stroop phenomenon. Several studies have revealed that the difference in performance on congruent and incongruent trials can arise from response interference. In contrast to this view, several authors have claimed that Stroop interference might occur at earlier processing stages related to semantic or conceptual encoding. The aim of present study is to determine the number and nature of the factors necessary to account the multiple components of Stroop interference.

**Methods**: The sample consisted of 247 undergraduate and postgraduate students. The computerized version of Stroop task adapted to Iranian Population was employed. An exploratory principal components analysis was conducted on the correlations of the six variables (reaction time under congruent and incongruent conditions, Omission error under congruent and incongruent conditions, and commission error under congruent and incongruent conditions).

**Results:** Two factors were extracted. The first factor seems to be semantic interference and the second factor seems to be response interference.

**Conclusions:** The findings of this research are consistent with multiple-stage account claims that Stroop interference is due to both semantic and response interference.



**Key words:** Stroop**,** Stroop interference, semantic interference, response interference




## 1. Introduction

What is required in a conflictual situation such as overcoming a habitual action in favor of an unusual one? It takes mind to involve at least three cognitive operations: to detect interference between two parallel processes, to make a decision (decide to focus on information related to the goal and at the same time to inhibit the unrelated information), and to inhibit habitual action (to form an output code based on the appropriate decision). These complex mental operations refer to *interference* resolution. Posner and colleagues (Petersen & Posner, 2012; Posner, 2008, 2012a, 2012b; Posner & Dehaene, 1994; Posner & Petersen, 1990; Posner, Rothbart, Sheese, & Tang, 2007) ascribe such an operation to *executive* network of attention (see Petersen & Posner, 2012 for reviewing this and two other attentional networks). The executive attention network detects error and resolve interference among contradictory parallel responses (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Petersen & Posner, 2012).

There are various cognitive tasks to measure interference between stimulus dimensions such as temporal dimensions (Nazari, Mirloo, Rezaei, & Soltanlou, 2016; Nazari et al., 2013) and spatial features (Simon & Berbaum, 1990; Simon, Sly, & Vilapakkam, 1981). The most widely studied is the classic Stroop interference between a word name and its ink color (MacLeod, 1991). The task originally developed by Stroop (1935). In Stroop task, Subjects see words that denote colors (red, green, blue, and yellow) printed in a corresponding color (e.g., the word *red* written in red ink) or in a noncorresponding color (e.g., the word *blue* presented in red ink) and subjects are required by instruction to name the ink color while inhibiting the meaning of the word. When the color and the word are *congruent*, the task is easy; when the color and the word are *incongruent*, people experience *interference* (MacLeod, 1991; Stroop, 1935).

The Stroop interference indicates reaction time (RT) is consistently longer in the incongruent trials compared with the congruent trials (see MacLeod, 1991, for a review). The interference occurs among the automatic process of word reading and the effortful process of color naming (Augustinova & Ferrand, 2014; Cohen, 1990; Luo, 1999; Schneider & Chein, 2003). Thus, the so-called *Stroop-interference* denotes the ability to inhibit a usual response (i.e., an overlearned response) in favor of an unusual one (Homack & Riccio, 2004).

The variety of Stroup test versions is one of the challenges of the literature. Many later studies (E. Y. H. Chen, Wong, Chen, & Au, 2000; Davidson & Wright, 2002; Farhadian, Akbarfahimi, Hassani Abharian, Hosseini, & Shokri, 2017; Hekmat, Alam Mehrjerdi, Moradi, Ekhtiari, & Bakhshi, 2011; Hinkin, Castellon, Hardy, Granholm, & Siegle, 1999; Rezaei, Ashayeri, Yazdandoost, & Asgharnejad, 2003; Saremi, Shariat, Nazari, & Dolatshahi, 2017) have implemented computerized stimuli that facilitate accurate measurement of reaction time (Homack & Riccio, 2004). There are two types of reaction time measurements: the reaction time for the verbal response and the reaction time for the motor response (pressing the button). Most studies have used the first type.

In recent years, questions have been raised about the nature of processing the interference. Lupker and Katz (1981) claimed that Stroop interference can occur at four possible stages or processes: (1) an input process; (2) a decision process; (3) a response selection process,; and (4) a response output process. There are two alternative explanations of Stroop phenomenon that correspond to the stages of information processing proposed by Lupker and Katz (1981).

Several researchers have explained that the difference in performance on congruent and incongruent trials can arise from *response interference* (Cohen, 1990; Duncan-Johnson & Kopell, 1981; MacLeod, 1991; Roelofs, 2003). Lupker and Katz (1981) claimed that in the *response selection* process an output code must be formed based on the appropriate decision (e.g., a phonetic representation in a naming task, a motor code representation in a button-pressing task, and so on). This means that presentation of the irrelevant word automatically activates the responses with a similar meaning. This facilitates response selection on congruent trials but interferes with response selection on incongruent trials (De Houwer, 2003).

Several authors (Brown & Besner, 2001; Davelaar & Besner, 1988; Green, Locker, Boyer, & Sturz, 2016; Hasshim & Parris, 2015; Klopfer, 1996; Luo, 1999; Seymour, 1977; White, Risko, & Besner, 2016; Williams, Mathews, & MacLeod, 1996) have claimed that Stroop interference might occur at earlier processing stages related to *semantic* or conceptual encoding. (Seymour, 1977) debated that Stroop interference occurs because *the to be-named color* and *the to be-ignored word* activate two similar semantic codes.

Many analysts (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004; Van Veen, Cohen, Botvinick, Stenger, & Carter, 2001) have claimed that the information is processed at different levels. As Van Veen et al (2001) argued: "Theoretically, interference might occur at any or all of these levels" (Van Veen et al., 2001). There was widespread behavioral (De Houwer, 2003; Schmidt & Cheesman, 2005; H. Zhang & Kornblum, 1998; H. H. Zhang, Zhang, & Kornblum, 1999) and neuropsychological (A. Chen, Bailey, Tiernan, & West, 2011; Z. Chen, Lei, Ding, Li, & Chen, 2013; Liu, Banich, Jacobson, & Tanabe, 2004; Melcher & Gruber, 2009; Taylor, Kornblum, Lauber, Minoshima, & Koeppe, 1997; Van Veen & Carter, 2005; Zysset, Muller, Lohmann, & von Cramon, 2001) support to give an account that both forms of interference contribute to the Stroop interference effect .

The aim of present study is to determine the number and nature of the factors necessary to account the multiple components of the Stroop interference. We conducted an exploratory factor analysis to claim that we did not make a priori assumption about the nature of interference.

## 2. Methods

### 2.1. Participants

Zanjan University consists of four faculties: agriculture, humanities, science and engineering. In each of the faculties, an announcement was issued to recruit volunteer students to participate. The sample consisted of 247 undergraduate and postgraduate students (see table 1 for demographic data).

Table 1

Demographic Data Describing Subjects

| | n | % |
|---|---|---|
| **Gender** | | |
| Female | 127 | 48.6 |
| Male | 120 | 51.4 |
| Total | 247 | 100 |
| **Age** | | |
| 18 | 7 | 2.8 |
| 19 | 19 | 7.7 |
| 20 | 47 | 19.0 |
| 21 | 47 | 19.0 |
| 22 | 41 | 16.6 |
| 23 | 32 | 13.0 |
| 24 | 21 | 8.5 |
| 25 | 11 | 4.5 |
| 26 | 7 | 2.8 |
| 27 | 4 | 1.6 |
| 28 | 4 | 1.6 |
| 29 | 4 | 1.6 |
| 30 | 3 | 1.2 |
| Total | 247 | 100 |

## 2.2 Measure

We employed a computerized version of Stroop task adapted to Iranian Population. This Persian version was developed by Ravan Tajhiz Sina Company. The software used the set of four stimuli defined by color words written in Persian alphabet: ﺑ ghermezﭖ(Persian word for ﺑ redﭖ), ﺑ sabzﭖ (Persian word for ﺑ greenﭖ), ﺑ zardﭖ(Persian word for ﺑ yellowﭖ), ﺑ Abiﭖ(Persian word for ﺑ blueﭖ) that presented in red, green, yellow and blue ink. All 48 Congruent stimuli were the color words presented in the corresponding ink (e.g., the word "blue" printed in blue ink), while 48 incongruent were the color words presented in the different ink (e.g., the word "red" printed in blue ink). the output was as: 1- *reaction time under congruent and incongruent conditions*: interval between the perception of the color of word and pressing the colored button; 2- *Omission error under congruent and incongruent conditions*: the failure to respond to target button; 3- *commission error under congruent and incongruent conditions*: responses are given to non-targets button (e.g., the subject press the "red" button when the "blue" ink is presented). *Interference reaction time* was calculated as the difference between the incongruent and congruent mean reaction times. the internal consistency of reaction times were reported as 0.6, 0.83, and 0.97 in three stage, respectively by Ghadiri, Jazayeri, Ashayeri, and Ghazi-Tabatabaei (2006). Internal consistency for errors numbers were also 0.55, 0.78, and 0.79 in three stage respectively. Several studies (Ghadiri et al., 2006; Hekmat et al., 2011; Rezaei et al., 2003; Saremi et al., 2017) have used Iranian version of computerized Stroop task to study neuropsychological substrates of psychiatric disorders.

**2.3. Procedure**

All 96 trials were randomly presented on the center of a 15-inch computer screen. Display time was 2 seconds and the inter-stimulus interval was 800 milliseconds. The response buttons were labeled with color patches in keyboard. Subjects were instructed to press the same color button as the word ink color.

**2.4. Data analysis**

Our analysis of the Stroop interference was based on the assumption that there is an observed interference as measured by the task we used. Thus we used related *t*-test to examine whether the Incongruent Mean RT is significantly different from the Congruent Mean RT. Moreover, an exploratory principal components analysis was conducted on the correlations of the six variables (see table 2 for correlational matrix).

**Table 2**

Correlations matrix of the six variables of computerized Stroop task

| Variables | Congruent Commission | Incongruent Commission | Congruent Omission | Incongruent Omission | Congruent Mean RT |
|---|---|---|---|---|---|
| Congruent Commission | | | | | |
| Incongruent Commission | .58** | | | | |
| Congruent Omission | .27** | .33** | | | |
| Incongruent Omission | .16* | .30** | .93** | | |
| Congruent Mean RT | .14* | .27** | .56** | .57** | |
| Incongruent Mean RT | .13* | .31** | .55** | .56** | .97** |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The Kaiser eigenvalue (Kaiser, 1960) criterion (i.e., eigenvalues > 1.0) was considered to determining the number of factors for extraction. Orthogonal rotation of the factors by the varimax method yielded the factor structure given in Table 3.

**Table 3**
**Rotated Component Matrix**

| | Component | |
|---|---|---|
| | 1 | 2 |
| Congruent Mean RT | .902 | |
| Incongruent Mean RT | .895 | |
| Incongruent Omission | .845 | |
| Congruent Omission | .823 | |
| Congruent Commission | | .904 |
| Incongruent Commission | | .847 |

# 3. Results

The Incongruent Mean RT (M = 959, SD = 175) and congruent Mean RT (M = 902, SD = 161) differ significantly, *t* (246) = 23, two-tailed p = .001. Thus, there is Stroop interference.

Two factors were initially extracted. The first factor accounted for 56 per cent of the variance and the second factor 23 per cent. The first factor seems to be *semantic interference* and the second factor seems to be *response interference*. Communalities (i.e., percentage of indicator variance accounted for by the solution) ranged from .75 (Congruent Omission) to .82 (Congruent Commission).

## 4. Discussion

In the present study, we utilized a manual response (button press) format of computerized Stroop task to explore the components of Stroop interfere. We found reaction time (RT) was significantly longer in the incongruent condition compared with the congruent condition that indicates the task elicited the Stroop interference. Furthermore, we found that incongruent trials showed significantly higher commission and omission errors than congruent trials, demonstrating that the task induced the Stroop interference. The present findings seem to be consistent with other research which found the Stroop interference in manual response task (Ila & Polich, 1999; Schmidt & Cheesman, 2005; Sharma & McKenna, 1998; Sugg & McDonald, 1994). This finding corroborates the idea of speed ت accuracy tradeoff (Fan, Flombaum, McCandliss, Thomas, & Posner, 2003; Fan, McCandliss, Sommer, Raz, & Posner, 2002; MacLeod, 1991; Stroop, 1935). It has been suggested that incongruent conditions result in longer RTs and higher error rates than congruent conditions, and vice versa. As a consequence of observing Stroop interference, we achieved our purpose of conducting an exploratory factor analysis. The analysis yielded two factors.

Increased *Reaction Time* (both Congruent and incongruent) together *omission error* increasing (both congruent and incongruent) loaded on Factor one. It seems to us that common features of this factor are compatible with *semantic interference*. Increased reaction time is taken to largely reflect semantic processing, such as whether the concept represented by color word and the concept represented by color ink are incongruent. It seems reasonable to assume that these effortful trials indicate the subjectِی ability to detect *semantic interference*. Adherent of semantic explanation believe that interference occur at earlier processing related to semantic encoding prior to response output. As we learned from (Seymour, 1977), the *to be-named color dimension of word* and the *to-be-ignored word* trigger two similar semantic codes. In a nutshell, it can be said that the main explanation for semantic competition is that Stroop stimuli trigger semantic representations of both color and word dimensions, and thus the semantic competition between these two dimensions is created before the response output (Green et al., 2016). Luo (1999) explained that Color naming requires the activation of an appropriate network in the verbal-lexical system. But word reading, requires only the activation of the relevant network in the lexical-verbal system, and in this case the operation of the semantic system is optional. The main cognitive challenge for the participant in our manual task and other versions is to *ignore* or *override* the semantic codes of verbal-lexical system for responding. If person fail to override, he will either respond long or will not select any response. Botvinick, Braver, Barch, Carter, & Cohen (2001) called the type of cognitive monitoring to inhibit the verbal-lexical system (word reading) as *response override* (Botvinick et al., 2001).

Our second finding was both congruent and incongruent *commission error* loaded on Factor two that called *response interference.* As we described, commission errors are made when responses are given to non-targets button (e.g., the subject press the "red" button when the "blue" ink is presented). According to Lupker and Katz (1981) these error can occur in third (a response selection process) and fourth stage (a response output process). In the response selection process an output code must be formed based on the appropriate decision (a motor code representation for button pressing task, e.g., the subject plan press the "red" button when the "red" ink is presented, and to inhibit other button press).

Returning to the question posed at the beginning of this study, it is now possible to state that our findings are consistent with multiple-stage account (A. Chen et al., 2011; Z. Chen et al., 2013; De Houwer, 2003; Liu et al., 2004; Melcher & Gruber, 2009; Schmidt & Cheesman, 2005; Taylor et al., 1997; Van Veen & Carter, 2005; H. Zhang & Kornblum, 1998; H. H. Zhang et al., 1999; Zysset et al., 2001) claims that the Stroop interference is due to both semantic and response interference (see Risko, Schmidt and Besner, 2006 for reviewing). These studies used many modified versions of the Stroop color-word task, by which they were able to separate semantic from response interference (for example, see De Houwer, 2003 for such a modified version of the stroop task). Van Veen & Carter (2005) used a modified version of the Stroop task, by which they were able to separate semantic from response interference through fMRI data. They identified both semantic and response interference elicits independent activation in anterior cingulate, prefrontal and parietal brain regions. They concluded that the brain has discrete and parallel attentional processes for resolving these diverse conflicts. Other neuroimaging studies have also demonstrated that there are two independent neural networks underlying semantic and response interferences in the Stroop task (A. Chen et al., 2011; Z. Chen et al., 2013; Liu et al., 2004; Melcher & Gruber, 2009; Taylor et al., 1997; Van Veen & Carter, 2005; Zysset et al., 2001).

Neuroimaging studies (Z. Chen et al., 2013; Egner & Hirsch, 2005; Liu et al., 2004; Ruff, Woodward, Laurens, & Liddle, 2001; Van Veen & Carter, 2005; Van Veen et al., 2001; Zysset et al., 2001) have shown activation of the dorsal anterior cingulate cortex (ACC) in Stroop and Stroop like tasks requiring people to override either a prepotent response or a rather strong conflicting dimension. These results propose the detection of interference for ACC as a definite executive function that occurs at response-related levels of processing.

It appears our findings are limited by the use of a manual version of Stroop task owing to its apparent motor component. Further exploratory and confirmatory factor analyses needs to be done to establish whether the vocal tasks support our findings including two types of interference.

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### Conflict of Interest

The authors declared no conflicts of interest.

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