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STROOP TASK AS A TOOL TO UNDERSTAND BILINGUALISM: A REVIEW

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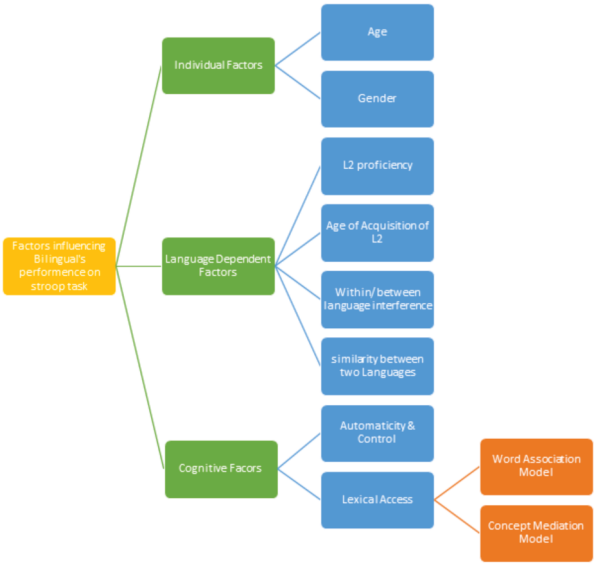
ABSTRACT Stroop task is one of the most widely used neuropsychological tests. Its ability to measure interference has made it an apt tool to understand bilingualism. In the past many researches have been done to understand how a bilingual's performance is affected by Stroop task. These studies have attempted to explore various factors that affect a participant's performance on Stroop Task. This review attempts to a) classify each of these factors into individual, cognitive and linguistic factors and b) understand and review each of those factors in detail.

KEYWORDS : Stroop Task, Bilingualism, Cognition

INTRODUCTION

Stroop task is one of the most widely used psychological test to understand interference in bilinguals. One of the critical characteristics of bilinguals is that they can use two languages with minimum interference from one language when using the other language. However, occasional interference between two languages suggests an overlap in both the languages. Stroop task that is traditionally used to measure interference thus becomes an apt tool to understand how interference occurs in two languages in bilinguals. In the bilingual version of color- word Stroop Task participants respond to the color of the color-word in both the language in which the color- word is written and the other language of the bilingual. Thus, this creates four conditions that is 1) responding to the color of the word written in the first language using the same language. 2) Responding to the color of the word written in the first language using the second language. 3) Responding to the color of the word written in the second language using second language itself and 4) responding to the color of the word written in the second language using the first language. Dalrymple-Alford (1968) was the first one to use Stroop task on bilinguals, followed by Preston and Lambert in 1969 and Dyer in 197l. Since then numerous studies have used Stroop Task to understand interference in bilinguals on various levels. Upon carefully reviewing several studies it was observed that bilinguals have common underlying factors that influence their performance on the Stroop Task. This review aims to examine and understand each of those underlying factors in detail. As shown in figure 1, common underlying factors of a bilingual person have been classified into 1) individual factors, 2) cognitive factors and 3) Linguistic Factors. The following section discusses each of these factors in detail.



STROOP TASK

Stroop task is one of the most well-known psychological tests. This task focuses on understanding fundamental cognitive functions of a person such as selective attention. In clinical neuropsychology, Stroop task is used as an executive functioning task (Lezak et al., 2004). The development of Stroop task has been credited to J.R Stroop whose classical article was published in 1935 in the Journal of Experimental Psychology. In his study, Stroop was mainly concerned with explaining interference and the effects that practice has on interference. However, the ground for Stroop's work was laid by James McKeen Cattell in 1886 who proposed that objects and colors take longer to read aloud when compared to words.

In the standard color- word Stroop test also called the serial color word Stroop Task the participants are required to name colors in three conditions. In neutral condition, a list of XXXX is printed in different colors and the participant is required to respond to the color of the ink. In the congruent condition, the participants are presented with color words that are printed with the same colored ink. E.g., the color red is printed in the red colored ink. In this condition, the participants respond to the color of the ink in which the word is printed. In the incongruent condition, the participants are presented with color words that are printed in the ink of different colors. E.g., the color red is printed in blue ink. In this condition, the participants respond to the color of the ink in which the word is printed and not the word itself. The difference between ink color and the color in which the word is presented thus creates conflict which leads to interference when the participant responds. This interference thus leads to different reaction times in different Stroop conditions.

Stroop task has been used extensively by the researchers to understand cognitive functions in a variety of research areas. One such area where the Stroop task has been extensively used is bilingualism.

BILINGUALISM

The term 'bilingualism' has been defined in different ways. For example, on one end Bloomfield (1935) defined bilingualism as 'native-like control of two languages on the other hand, Macnamara (1967a) defined bilinguals as those who posess minimal competence in one of the four: language skills, listening comprehension, reading, speaking and writing, in a language other than his/her mother tongue. More recently Mohanty (1994) defined bilingual persons or communities as those with the ability to meet the communicative demands of the self and the society in normal functioning.

Mackey (1967) suggested four questions that must be addressed when describing bilingualism: degree, function, alternation, and interference. Degree refers to an individual's proficiency in each of the two languages. Function refers to what use the languages have for a bilingual speaker and the roles these languages have in the person's total repertoire. Alternation refers to the extent to which the individual alternates between the languages and interference refers to the extent to which the individual keeps the languages separate or fused.

Bilinguals ability to direct attention and control to one language system while supressing interference from the other language system have shown them to have cognitive advantage in performance on various tasks that involve interference suppression and task switching. Tasks like Eriksen Flanker, Simon Task, number–letter switching, *n*-back task and Stroop Task have been widely used to understand these phenomenon in bilinguals (Yow and Li, 2015).

STROOP TASK AND BILINGUALISM

Bilinguals require controlling two languages. Response inhibition and interference that are traditionally assessed using stoop task has made this task very widely used in bilinguals to understand how bilinguals process, maintain, use and control two languages simultaneously. The research in the area of how language differences affect an individual's performance on the Stroop task began with the work of Dalrymple-Alford (1968). Since then numerous studies have been published that have assessed several factors that influence a bilingual's performance on Stroop task. For classification these factors have been grouped into individual, cognitive and linguistic factors. Individual factors are concerned with how a bilingual person's age, gender, and education affects his performance on Stroop task. Cognitive factors focus on the mental processes that help bilinguals to access, control and produce two languages simultaneously and the linguistic factors are the ones those are dependent on a particular language per se such are how differences in the script of two languages used by bilinguals. The following section aims to review and summarize research findings for each factor.

FACTORS AFFECTING BILINGUAL'S PERFORMANCE ON STROOP TASK

1. INDIVIDUAL FACTORS

Individual factors comprise of age, gender, and education of the bilingual.

a. The Effect of Age

The interest to study the effect of age on performance in the Stroop Task arose in mid- the 1960s. Comalli and his colleagues in 1962 conducted one of the first studies and concluded that greatest interference occurred in young children, but as the reading skills developed, interference declined in adulthood and then again increased beyond 60 years of age (Mc loed 2000). Similar results were found by Ivnik et al. in 1996. According to them performance of the participants on the subtests of golden Stroop Task significantly declined with advancing age.

Following these studies, as the research interest grew in the area of bilingualism, several researchers became curious to understand how age played a role in bilingual's performance on Stroop Task? In the recent years, studies have compared bilingual's performance with monolingual's performance. Studies done on children, young adults and old adults have shown that the extensive use of executive control processes that are required in manipulating two languages in bilinguals, provided them with an advantage on tasks that require attentional control (Kousaie and Phillips, 2012).

Cognitive view suggests that decline in inhibition causes age-related changes in cognition (Hasher & et al., 2004). Zied et al. in 2004 studied how younger and older bilinguals (French and Arabic) performed on the Stroop task. They found that both young and old balanced bilinguals (bilinguals who were equally proficient in both languages) responded more quickly in all conditions of Stroop task when compared to language dominant bilinguals. The researchers also reported that older adults with a dominant language also showed the greatest interference in interlanguage condition (i:e, where the stimulus is presented in one language and response, is given in the other language). One of the important conclusion drawn by Zied et al. from this study was that the performance of balanced bilinguals showed that controlling two languages could improve the efficiency of inhibitory mechanisms. Other conclusions drawn from the study were; firstly, efficiency in inhibitory processing declined with age. Secondly, for unbalanced bilinguals or bilinguals who were dominant in one language, control of language systems may have been asymmetrical. Thirdly, if the person was more proficient in one language when young, he/she remained equally proficient in that language when old and non-dominant language was disturbed and showed a more rapid decline in old age. In a study, Bialystok et al. (2008) attempted to study executive control using the classical version of Stroop task among other factors in ninety- six young and old monolinguals and bilinguals and found that younger participants responded more quickly on Stroop task as compared to older participants. Also, bilingual participants responded more quickly than monolinguals on the Stroop task. Similar results were found by Rosselli et al. in 2001.

Hence, the dominant view suggests that Stroop effect is greater in old adults compared to young adults. This view is consistent with the hypothesis that there as there is age-related decline in inhibitory control processes that allows irrelevant information to enter working memory and to receive sustained activation. However, in a more recent study conducted by Kousaie and Phillips in 2012, no bilingual advantage was found in young or old adults on Stroop Task

b. The effect of Gender

Majority of the research has failed to find any gender differences among men and women on the Stroop task. Few researchers have however proposed that women are faster in naming colors as compared to males. For e.g., in a study conducted by Van der Elst et al. in 2006 females performed faster than men on color- naming cards and interference but not on reading names of colors. Baroun and Alansari in 2006 also reported similar findings. They proposed that shorter latencies in females could be ascribed to their verbal and fine motor skills. Studies have also reported that larger brain areas such as callosal area and planum temporale in women may have been responsible for their better performance in Stroop task compared to men (Burke & Yeo, 1994; Goy & McEwen, 1980; Kimura, 1987).

More specifically, research involving bilingual participants also did not show any gender differences. Lee and Chan (2000) conducted a study on eighty- five Chinese- English bilinguals and English monolinguals. They failed to find any gender differences in performance on the Stroop task in either Chinese or English language. Baroun and Alansari (2004) conducted a study on 140 Kuwaiti and 70 British university students and failed to find any gender differences on the Stroop task. Hence, when it comes to gender, most studies have found similar results for both monolinguals and bilinguals.

COGNITIVE FACTORS

Cognitive factors focus on mental processes that are involved in processing, controlling and maintenance and production of both the languages used by bilinguals. Researchers have used the Stroop Task to asses a variety of these cognitive factors in bilinguals. These include automaticity and control and lexical access.

a. Automaticity and Control

Automaticity is defined as the absence of attentional control while performing a cognitive activity (Kahneman, 1973). Automatic process is unconscious and effortless. Automatic processes are also involuntary in that they occur unintentionally, they cannot be fully suppressed, once activated they lead to completion (a process known as ballisticity) and their products cannot be ignored (Hasher & Zacks, 1979 and Shiffrin & Schneider, 1977). Executive control, on the other hand, is the ability of an individual to resist interference and to act according to the goal (Gray, Chabris & Braver, 2003). Executive control thus involves conflict monitoring and conflict resolution. Although, both automaticity and executive control are considered as opposing concepts, both require highly skilled performance (Tzelgov, Henik & Leiser, 1990). Stroop Effect has been widely used to understand automaticity and control in bilinguals. Verguts and Notebaert (2008) proposed that cognitive control triggers the neuromodulatory system that is involved in arousal and influences the binding of active representations online via Hebbian (associative) learning. Therefore, Hebbian learning is increased in conflict situations due to increased modulation of the arousal system, and in turn, yields better cognitive control.

Tzelgov & Kadosh in 2009 extended a model proposed by Verguts and Notebaert (2008) to explain how increased automaticity is linked with increased cognitive control in bilinguals as depicted by Stroop effect. According to this model, Greater automaticity occurs in the first language as the Stroop effect is more for the first language compared to the second language. Also, cognitive control is greater for the first language because when the proportion of trials in both the languages is manipulated, an increase of stimuli in the first language (in both congruent and incongruent condition) leads to a decreased Stroop effect in the first language, whereas the second language is much less sensitive to the manipulation. Further, adding less practiced words of the second language allows greater automaticity in the first language (such as increased Stroop effect) in the first language. This leads to an increased degree of arousal and activation for locus coeruleus for the incongruent trials in the first language as compared to the second

language. The increase in arousal then in turn increase control with a specific lexicon via binding. This binding by associative learning is a positively accelerating function of the conflict level, and thus the learning leads to increased control only for the first language where the conflict (and therefore arousal) is high enough. Therefore, the end result is a more efficient cognitive control for the first language compared to the second language (Tzelgov & Kadosh, 2009).

b. Lexical Access

To understand how languages are structured and represented in memory researchers have proposed several theories. One view suggests that for each language words are stored in separate lexicons while the concepts of these words are connected at the semantic level. The other view suggests that words are stored in a common, conceptual supra-linguistic memory structure (e.g. Kolers and Gonzalez, 1980; Paivio, Clark and Lambert, 1988). To reach on a consensus of these two opposing viewpoints researchers have proposed that memory in bilinguals consists of a lexical level at which the words are stored and a conceptual level at which that semantic features of those words are stored. Researchers have further proposed specific models to understand how the connections within and between the lexical and conceptual level of representation occur. According to the word association model there is a direct link between the first and the second language of a bilingual and the first language is directly connected to the underlying conceptual store. For example, a bilingual speaker may access the meaning of a word of the second language by first translating that word in the first language at the lexical level and then retrieve the meaning of that word from the conceptual store. The concept mediation model proposes that first and the second language do not have a direct link at the lexical level. This model proposes that lexicons of both the languages are connected to a common semantic representation. In this model, the underlying concept mediates processing across both languages (Altarriba and Mathis, 1997). When applying these models on bilinguals to assess their performance on Stroop task Rosselli et al. (2002) suggested that if the word association model is true more interference should occur in the between language conditions of the Stroop task but if the concept mediation model is true more interference should occur in the within language conditions in the Stroop task. In their study on Spanish- English bilinguals, Rosselli et al. (2002) found that the type of interference varied among bilingual groups. The unbalanced bilingual group showed more interference on the within language conditions on the Stroop task as compared to between language conditions. The balanced bilingual presented relatively small interference levels that were similar in both within and between language conditions. Their results, however, did not support either word association or concept mediation model.

LINGUISTIC FACTORS

Linguistic factors are dependent on the language itself.

a. The effect of second language proficiency

Language proficiency has been shown to effect a bilingual's performance on the Stroop task. Research studies have consistently shown that in a highly proficient bilingual both languages are simultaneously active, even when the person is engaged with one single language (e.g., Blumenfeld & Marian, 2007; de Groot, Delmaar, & Lupker, 2000 ; KerHeuvenkhofs, Dijkstra, Chwilla, & de Bruijn, 2006; Dijkstra, Grainger, & van Heuven, 1999; Kousaie & Phillips, 2011; Libben & Titone, 2009; Paulmann, Elston-Güttler, Gunter, & Kotz, 2006; van Heuven, Schriefers, Dijkstra, & Hagoort, 2008). According to Bialystok & Craik, (2010) Bilinguals require executive control process to manage two language systems simultaneously. This process is unique to bilinguals because when a bilingual is using one language attentional mechanisms maintain focus on the target language and reduce interference from the non- target language. Thus, as compared to monolinguals, bilinguals acquire extensive practice in reducing interference. Few studies have further explained bilingual advantage in terms of goal maintenance and conflict resolution (Abutalebi & Green, 2007; Bialystok, 2009; Costa, La Heij & Navarrete, 2006). These studies have proposed that first (L1) and second (L2) language systems of bilinguals creates a conflict for selection. Therefore, bilinguals need to monitor their attentional mechanisms to the target language continuously, this is called goal maintenance. Bilinguals also need to inhibit the non- target language from avoiding confusion in language processing; this is called conflict resolution. In a study, Tse & Altarriba (2012) found that first and second language proficiency influences bilingual's selective attention performance on Stroop task by affecting conflict resolution and goal maintenance. They also found that, firstly, participants responded faster as their proficiency in the second language increased. Secondly, the extent to which the participant's reaction time decreased in incongruent trial's as compared to congruent trials was associated with their proficiency in the first/ second language. This indicated the effect of bilingual's language proficiency on conflict resolution. Singh and Mishra (2012) conducted a study on Hindi and English bilinguals using oculomotor Stroop task. Participants in this study differed in their second language proficiency. The task required participants to make eye movement towards the color patch that was the same as the color in which the color- word presented in the center was written. The participants were required to resist interference from the meaning of the word. The results depicted that participants who were highly proficient in the second language showed an overall advantage in speed and conflict resolution as compared to participants who were less proficient.

b. Age of Second Language Acquisition

According to the bilingual cognitive advantage hypothesis, bilinguals have cognitive advantage by maintaining attention and control in the appropriate language. This cognitive advantage is dependent upon factors such as exposure and practice in monitoring and controlling attention in both language systems. For e.g. increased use of two languages by a bilingual will make him/her more proficient in both languages. Early acquisition of both languages in bilinguals thus provides them with exposure and practise in using and controlling both the languages. Thus, regular use of two languages helps bilinguals to direct more control and attention towards preventing interference from the inappropriate language system. Yow and Li (2015) conducted a study on seventy two English- Mandarin bilinguals using Stroop Task and found a significant positive association between age of second language acquisition and interference in Stroop task. However, opposing results were found by Rosselli et al. in 2001. In their study on 71 Spanish- English bilinguals and 40 English monolinguals, Rosselli et al. concluded that age of acquisition did not predict participant's performance on Stroop Task.

Studies that attempt to understand how age of second language acquisition affects bilingual's performance on Stroop Task thus show mixed findings. More research is needed in this area in the future to reach to a definitive conclusion.

c. Within/ Between Language Interference

The bilingual version of the Stroop task requires participants to respond to color words in both dominant (first language) and non-dominant language (second language). In this task, participants are presented with trials in both, dominant and non- dominant language and their responses yield two within language and two between language interference scores. In the within language condition, the participants are presented with a) words in the first language and are asked to respond in the first language and b) words in the second language and are asked to respond in the second language. In the between language condition the participants are presented with a) words in the first language and are asked to respond in the second language and b) words in the second language and are asked to respond in the first language. The interference scores on these four conditions provide a conclusion about the within and between language interference. Majority of the studies have concluded that within language interference in more than between language interference (MacLeod, 1991). However, the ratio of within language to between language interference has been shown to vary considerably.

Results of the study conducted by Shishkin and Ecke (2018) on Russian- English bilinguals did not conform to previous findings. Their study did not show greater within language interference as compared to between language interference.

d. Similarity between two languages

Different scripts are processed differently in the brain . Studies have shown that variation in scripts of two languages leads to differences in how and where each script is processed in the brain. (Nakamura et al., 2005 and Thuy et al. 2004). For example, studies have found that languages with logographic scripts such as Chinese activate neural systems primarily in the left middle frontal gyrus and areas of the ventral occipitotemporal system. Languages with alphabetic scripts such as English, on the other hand, activate left temporoparietal system, left inferior parietal cortex, supramarginal gyrus and ventral occipitotemporal system (Tan et al. 2003, Tan et al. 2005, Siok et al. 2004 & Bolger et al., 2005).

Lee et al. (1992) conducted a study on Chinese, Malay and Indian children of Singapore who were bilingual in both English and their respective mother tongue. These children were examined on the Stroop color-naming task in both inter and intralingual conditions. Contradictory to what was predicted according to the orthography-specific hypothesis, the results showed that logographic script did not induce greater intra-lingual interference when compared to the sound-based syllabic or alphabetic script. The results also did not show an increase in the reduction of interference from intra-language to interlanguage conditions as the orthographic structure of two languages increased. This result was contrary to what was noted by Fang et al. (1981).

Coderre & Heuven (2014) conducted a study on English monolinguals, German-English, Polish-English, and Arabic-English bilinguals using Stroop and Simon task and found that bilinguals with similar language scripts were more effective in the domain-general executive control as compared to bilinguals with different language scripts. Thus script similarity is an essential factor to consider to understand executive control in bilinguals.

CONCLUSION

Thus the Stroop Task has a dual relationship with bilingualism. It can be used to study language processing in bilinguals and on the other hand, bilingualism itself can effect performance on Stroop task. The effect of bilingualism and use of Stroop is important in today's time when populations are becoming migratory and international boundaries are disappearing. The processing of languages and executive control need to be studied in the light of these developments and more research is needed to study the cognitive processes using various tools in bilinguals.

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