

Dorota Ackermann-Szulgit
Magdalena Zubiel-Kasprowicz

Katedra Nauk Społecznych
Wyższa Szkoła Bankowa w Toruniu

Stroop Effect Test administered by Polish students in Polish and English

Introduction

In the 30's of the 20th Century, John Ridley Stroop found that some highly automated activities, such as reading a word, strongly interferes with the little automated process that involves naming the color in which the word is written. In Stroop's experiment, the subjects read the words naming colors at the same rate, no matter in what color they were written. However, when they had to name the color of the word, they did it at a much slower rate if the stimuli were inconsistent and faster if they were consistent with the rate of naming colors of the color bars. It takes more time to name a color or object than to read words representing their names. It turned out that color naming is less automated; therefore, it takes more time than reading a word list aloud. Stroop Test is considered an indicator of operational memory, concentration capacity or executive control [Jodzio, 2008]. Stroop Test is currently used widely in psychiatry and neurology. This method is used to evaluate the efficiency of executive functions related to the ability to inhibit a habitual reaction and the ability to switch to a new, previously unsuccessful response criterion [Tomaszewska, 2010]. The key phenomenon in the Stroop Test is the interference effect associated with a prolonged response time when a person is expected to react according to a new criterion that is different from that learned in the first part of the test. At the same time, the subject is still reminded of the previous criterion and must ignore the rule that has already been changed in the current task. Studies conducted by R. Stroop almost half a century later were replicated by MacLeod – this researcher obtained results convergent to those received by Stroop in his first studies [MacLeod, 1991; Nęcka et al., 2006].

Neuroimaging studies indicate that the performance of the Stroop Test is associated with activation of the anterior cingulate cortex. However, there are indications that it is the extensive network of the brain that constitutes the prefrontal cortex and the parietal and temporal lobes [Alvarez, Emory, 2006] that is responsible for the proper performance of the test. It is generally accepted that the Stroop Color and Name Reading Interference Test examines cognitive ability in situations where verbal perseveration is provoked. This test is also used to measure inhibition control in conflict situations [Royall et al., 2002; Jodzio, 2008]. Neuropsychological data that is a source of knowledge about the neuropsychological processes involved in this was collected from healthy subjects and people with cerebral dysfunction such as Parkinson's disease [Jodzio, 2008, Ackermann-Szulgit, 2012]. Correct performance of the Stroop Test requires efficiently-functioning frontal areas of the brain that are associated with inhibitions and response control. In the study of ERP (*event-related potentials*) in healthy subjects, higher activity was observed on the lateral surface of the prefrontal cortex and in the anterior cingulate cortex (ACC) [West and Bowry, 2006]. The role of individual structures in the brain in the correct execution of the test is still unclear, despite the popularity of neuropsychological testing throughout the world. In diagnostic practice, Stroop Test is used to study verbal operational memory, speed and fluency of reading and attention processes [Ackermann et al., 2003]. Currently, different versions of the Stroop Test are used in neuropsychological diagnostics in about 50% of neuropsychologists surveyed [Alvarez and Emory, 2006].

Most language processing occurs in the dominant hemisphere. In right-handed people, it is usually the left hemisphere. The right hemisphere, however, is associated with subtle analysis, metaphor reading and sense of humor. Traditionally, Broca's area was once considered a speech generator. On the other hand, Wernicke's area was referred to as the receiver. Language competence should not, however, be treated modularly. The motor center of the language, or Broca's area, is also activated during speech perception. On the other hand, the reception center, or Wernicke's area, is active in the production of speech. The neural network encoding the words is a network that is their biological substrate, that is, a set of neurons connecting phonological and perceptual functions with information about action or image. In the case of processing words describing the movement to the Wernicke's and Broca's systems, the areas of the prefrontal cortex, which encode the words associated with the action, are activated. Words related to visual aspects activate, in addition to the Wernicke's and Broca's systems, lower areas of the temporal cortex and the occipital lobe. Depending on the category of words, relevant areas of the brain are included in the language processing network. At this point, the functions of mirror neurons in language processing merits attention as well. These neurons are activated not only during observation of action or while listening to the sounds of this action but also during semantic analysis of speech containing words describing a given semantic category. The information that forms a specific concept in the brain is represented in a variety of ways and involves different areas, specialized in other functions than

linguistic. Such a prosaic notion as an apple engages visual areas, but also the areas that are responsible for coding the purpose of a fruit. The area of the network that is stimulated depends on the context. Apart from the linguistic context, recent studies mention the experience of the individual together with his/her past experiences and the individual history that affect the development of the human brain.

In 1997, Hirsch and his team of researchers [Hirsch et al., 1997] defined Broca's system areas that are used by people speaking in a foreign language. It turns out that humans use different regions of the Broca's area to produce a foreign language, depending on whether the language was acquired in childhood or in adulthood. Wernicke's area, which is located in the back of the temporal lobe, plays an important role in the understanding of language. This center, however, does not exhibit any or only very small differences in activity, given the age of acquiring the ability to use the language. The structures responsible for processing foreign languages are located in both hemispheres. The results of some studies indicate that foreign language structures are located in the right hemisphere. The earlier the language is absorbed, the greater is the involvement of the left hemisphere. In the natural assimilation of foreign language simultaneously with the first, the left hemisphere takes over functions of both systems. Later, after acquiring the native tongue, they are usually located in the right hemisphere. Thus, the right hemisphere specializes in routine expressions like *good morning, how are you* and grammatical expressions. The left, however, is involved in less frequently used vocabulary, characteristic for people with higher language competence. Language learning is controlled by the left hemisphere as an analytical and intellectual process. Natural assimilation, as a process of unconsciousness, can be dominated by the right hemisphere. The process of assimilation in the initial phase is controlled to the higher extent by the right hemisphere. It is only around the five years of age that the left hemisphere engages. In the next stages, this process becomes more analytical, formal and cognitive. Dominance of the hemispheres in the process of assimilation of a foreign language depends on many factors, such as whether the second language is assimilated with the first in early childhood, whether the second language was acquired naturally or learned formally, whether the assimilation involved child's register or the adult register and finally, whether learner treated the process itself analytically or learned the whole structure.

Material and method

Testing included 26 subjects: 13 women and 13 men aged 19 to 47. The mean age of the study group was 30 years, with 29 years for women and 31 years for men. All subjects declared secondary education. Three criteria were set for the inclusion in the study group. The first was the use of native Polish. The second criterion was knowledge of the color names in English, without the declared level of knowledge of the language where the subjects did not use the language on a daily basis. It should be noted that none of the subjects spoke English as a native tongue. The last criterion by

which people were qualified for the study was the ability to distinguish and name colors. All subjects were right-handed. Respondents were recruited from among WSB students in Bydgoszcz. Participation in the study was voluntary where each participant provided a written consent.

A house-developed test version was used for testing. Because of the lack of Polish adaptation of the test, this version was created based on the descriptions available in the literature. Stroop test consists of two parts, with 10 rows of words that are color names, 5 words in each row – 50 words in total. The first part of the Stroop test, where the words are printed in black, known as *reading color names printed in black* – RCNb, the task of the respondent is to read the words as quickly as possible. In the second part of the test, which includes naming color or word test where the color of the print and the word are different (*naming color of word different* or NCWd) the respondents are presented with words in a font of a different color than the meaning of the word being the color name¹ and the task of the respondent is to call the color of the font as quickly as possible while neglecting the meaning of words. According to classical assumptions, the first part of the test evaluates the speed and accuracy of the words being read, while the second part makes it possible to assess the operability of verbal memory and the executive functions described as behavioral elasticity and perseveration sensitivity [Stroop, 1935; Lezak et al., 2004].

The task of the subjects was to test the two parts of the test 3 times.

1. The first time respondents performed the RCNb and NCWd parts in Polish version.
2. The second time they performed both parts, RCNb and NCWd in English version.
3. The third time, respondents performed the RCNb English version part in English and the NCWd English version in Polish (English color names yellow, green, blue were named in Polish red, black and green [czerwony, czarny, zielony]).

Operationalization of variables and their indicators are presented in Tables A and B.

Table A. Dependent variables and their indicators

Dependent variable	indicator
Reading speed and fluency	• Run time measured in seconds of RCNb part • Number of errors in RCNb part
Verbal operational memory	• Run time measured in seconds of NCWd part • Number of perseverative errors in NCWd part

Table B. Independent variables and their indicators

Independent variable	indicator
Performance language	• Polish • English

¹ For example, red, green, yellow.

The results obtained² were analyzed statistically using STATISTICA 10.0. The variance analysis method was applied to repeatable measurements – Fisher’s [exact] test was used, followed by post-hoc analysis.

Results

The differences between the groups of women and men were compared using the Student’s t-test (Student’s t-distribution test). There were no significant differences in the time difference or the number of errors in the different parts of the test. In view of the above, the further post-test analysis was applied to the whole group without division by sex.

The analysis of the Fisher’s test variance was performed for three attempts of RCNb part. Results are presented in Table 1.

Table 1. Fisher Test Results for the RCNb part of Stroop Test.

Fischer’s test	Significance level p
F (2; 24) = 11.56	P <0.001

The analysis showed that the language (Polish or English) influences the timing of the RCNb part of the Stroop test. Post-hoc analysis was used to locate differences in individual measurements. Results of the post-hoc analysis are presented in Table 2. Bold fonts indicate significant statistical differences.

Table 2. Results of the post-hoc analysis for performance times of the RCNb part of Stroop Test.

Test part	Average execution times in seconds	RCNb POL	RCNb ENG	RCNb ENG2
RCNb POL ³	27.73		0.000949	0.000103
RCNb ENG ⁴	25.04	0.000949		0.313950
RCNb ENG2 ⁵	24.27	0.000103	0.313950	

Statistically significant differences were observed during RCNb parts execution between:

² The above analysis study was performed on raw results.

³ Part RCNb – Attempt 1 in Polish.

⁴ Part RCNb – Attempt 2 in English.

⁵ Part RCNb – Attempt 3 – repeated attempt in English.

- Attempt 1 – performed in Polish and Attempt 2 – performed in English and
- Attempt 1 – performed in Polish and Attempt 3 – re-performed in English

The respondents were much quicker to read color names in English than in Polish. There was no learning effect when re-reading these names in English.

Analysis of variance with Fischer Test as performed for three NCWd attempts. Results are presented in Table 3.

Table 3. Fisher Test Results for the NCWd part of Stroop Test.

Fischer's test	Significance level p
F (2; 24) = 40.41	P < 0.001

The analysis showed that the language (Polish or English) influences the timing of the NCWd part of the Stroop test. Post-hoc analysis was used to locate differences in individual measurements. Results of the post-hoc analysis are presented in Table 4. Bold fonts indicate significant statistical differences.

Table 4. Results of the post-hoc analysis for performance times of the NCWd part of Stroop Test.

Test part	Average execution times in seconds	RCNb POL	RCNb ENG	RCNb POL2
NCWd POL ⁴	50.12		0.000118	0.000514
NCWd ENG ⁵	67.12	0.000118		0.000062
NCWd POL2 ⁶	37.78	0.000514	0.000062	

Statistically significant differences were observed during performance of the RCNb part between:

- Attempt 1 – performed in Polish and Attempt 2 – performed in English and
- Attempt 1 – performed in Polish and Attempt 3 – re-performed in English after the prior performance of the RCNb part in English and
- Attempt 2 – performed in English and Attempt 3 – re-performed in Polish after the prior performance of the RCNb part in English.

The longest execution time was recorded in Attempt 2, when respondents used

⁶ Part NCWd – Attempt 1 in Polish.

⁷ Part NCWd – Attempt 2 in English.

⁸ Part NCWd – Attempt 3 in Polish.

English to name the font color in the English version. The shortest part of this test was during Attempt 3 when they named the font color in Polish in an English test version.

The Fischer Test variance was analyzed for the number of errors in three attempts in the NCWd part. Results are presented in Table 5.

Table 5. Fisher test results for errors in NCWd part.

Fischer test	Significance level p
F (2; 24) = 6.72	P <0.003

The analysis showed that the language (Polish or English) influenced the number of errors in the NCWd part of the Stroop test. Post-hoc analysis was used to locate differences in individual measurements. Results of the post-hoc analysis are presented in Table 6. Bold fonts indicate significant statistical differences.

Table 6. Results of the post-hoc analysis for performance times of the NCWd part of Stroop Test.

Test part	Average number of errors	RCNb POL	RCNb ENG	RCNb POL2
NCWd POL ⁷	0.62		0.382913	0.011099
NCWd ENG ⁸	0.81	0.382913		0.001357
NCWd POL2 ⁹	0.04	0.011099	0.001357	

Statistically significant differences were observed during performance of the NCWd part between:

- Attempt 1 – performed in Polish and Attempt 3 – performed in Polish after the prior performance of the RCNb part in English and
- Attempt 2 – performed in English and Attempt 3 – re-performed in Polish after the prior performance of the RCNb part in English.

The lowest number of errors was made by respondents in Attempt 3, when they named the English print in Polish. A similar number of errors (statistically insignificant) was made by respondents during Attempt 1 in Polish and Attempt 2 in English.

⁹ Part NCWd – Attempt 1 in Polish – number of errors.

¹⁰ Part NCWd – Attempt 2 in English – number of errors.

¹¹ Part NCWd – Attempt 3 – repeated performance in Polish after the prior performance of the RCNb part in English – number of errors.

Discussion

Based on the obtained data, it was confirmed that Polish students, regardless of gender, read the color names in English faster than in Polish. One possible reason for this situation may be that English color names are shorter than Polish. Examples may be red-*czzerwony* or blue-*niebieski*. In Polish, these are 3-syllable words, but in English they are monosyllabic words, which require much less time when they are performed verbally. In addition, the time taken to perform the test in different languages may also be influenced by the fact that a different hemisphere – left – dominates in native language processing, while the other – right – in foreign language processing.

Stroop effects were observed both in the Polish and English versions of the test. The average time spent on the NCWd part in the English version was slightly longer, but not statistically significant compared to the Polish version. This can be attributed not only to the slow down resulting from Stroop effect but also to the fact that the test subjects spent more time naming the color of the font in a foreign language than in the native tongue. The results of Attempt 3 were most intriguing when test subjects named the color in Polish in the English version of the test. During this test, NCWd part was performed most rapidly in comparison to the two previous attempts, with the differences being statistically significant. These results may indicate that in this case no Stroop effect occurred or occurred to a little extent. Presumably, the English language color labels did not interfere with the naming of the color names in Polish. There was no inhibition control of the previously learned reaction in the subjects because there it was not necessary. Although respondents were still reminded of the previous criterion (reading the color names), they did not have to ignore the rule, which in the current task has already been changed because it seems that this previous rule did not apply. Thus, they did not want to read color names written in English while they were asked to name the color of the font in Polish. It should be emphasized that when performing RCNb and NCWd parts in English, such control of the inhibition of the previously learned reaction was observed. This may indicate that verbal perseveration can also be triggered in a foreign language. Perhaps in the case of people who do not speak fluent English every day, the processing of these two languages involves other areas of the brain; therefore, there was no conflict in this task. This may also indicate the number of mistakes made by the respondents. These errors are also typically linked with the inhibition control of previous reactions. The smallest number of errors was recorded in Attempt 3 – it is worth noting that it is less statistically significant than in the Polish and English versions. There were no statistically significant differences in the number of errors made by the subjects in Attempts 1 and 2. Persons interviewed in both native tongue and foreign language made perseverative errors, with slightly more mistakes made in foreign language, which may be associated with a less automatism of activity of naming colors in a foreign language compared to naming those colors in the native tongue.

The results obtained in this study may shed new light on neuronal linguistic processing mechanisms, therefore authors plan to investigate this phenomenon more closely with those who are fluent in English where Polish is their mother tongue.

These data point to the need for further research in this field, but at the same time indicate a possible new use of the Stroop test in the study of neuronal foreign language processing.

Conclusions

1. The language affects the timing of the RCNb part of the Stroop Test. The respondents were quicker to read color names in English than in Polish.
2. The language affects the timing of the NCWd part of the Stroop Test. The respondents needed most time to read color names in English in the English version. The quickest performance time task was when they named the font color in Polish in an English language version.
3. The language affects the timing of the NCWd part of the Stroop Test. The results of Attempt 3 were the most correct when test subjects named the color in Polish in the English version of the test. It was in this attempt when the respondents made the lower number of perseverative errors.
4. It can be concluded that other areas of the brain are involved in the processing of native tongue and foreign language in people who do not use a foreign language every day.
5. Stroop Effect also known as a demonstration of interference in the reaction time of a task occurs in both the native and foreign language.

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Stroop Effect Test administered by Polish students in Polish and English

Abstract: Objective: The aim of the study was to investigate the influence of foreign language on the performance of the Stroop Test by Polish students.

Material and method: Testing included 26 subjects: 13 women and 13 men aged 19 to 47. In the first part of the RCNb test (*reading color names printed in black*), subjects read words denoting colors written in black. In the second part of the NCWd test (*naming color or word where the color of the print and the word are different*) subjects named the color of the font that was used to write the color word.

Results: Significant statistical differences in the timing of the two parts of the test were found in relation to the language. Faster execution time for RCNb parts was reported for English tests. In the case of RCNb parts, the fastest time was reported when naming the font color in Polish on an English-language version. In the same situation, the smallest number of errors was reported.

Conclusions: Foreign language influences the performance of the Stroop Test.

Keywords: Stroop test, neuronal processing of foreign languages, interference, persuasive errors, verbal memory