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RIGHT VERSUS LEFT HEMISPHERIC PROCESSING OF LANGUAGE IN NEUROPSYCHOLOGY

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Abstract

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

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

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smallest number of errors was reported. Foreign language influences the performance of the Stroop Test.

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

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 (Mac Leod, 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 poten-*

tials) 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 lan-

guage. 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.

The aim of this research was to confirm the thesis stating that different brain areas are responsible for mother language processing and different for the processing of the acquired language. Research making use of the Stroop test were carried out with the assumption that a braking effect with interference shall occur during mother language processing while during acquired language processing the interference effect shall not occur.

The first thesis was the thesis concerning the errors made during text processing. Poles in Polish version will make more mistakes than in English version. The second thesis was the thesis referring to interference effect. The interference effect disappears when the test is carried out on the basis of English terms when the colours should be named in Polish. This happens as probably different brain areas are responsible for mother language processing and different for the processing of the acquired language.

1. Research methodology

It should be noted that so far, in European reference books, the Stroop test was not used to indicate differences in mother tongue and acquired language message processing. It is the first attempt to deal with the research using the tool for testing the ability of language processing (mother tongue and acquired language), as so far, the Stroop test was used in clinical trials in neuropsychological assessment. A specially

designed test based on Stroop test was used during the research, that on the basis of the original test form tested operational memory, the ability to focus and executive control. In the traditional Stroop experiment, the person being tested read the terms defining colours at the same speed, no matter in what colour they were written. But when they had to name the colour in which the word was written down they did it slower if the stimuli were inconsistent and faster if they were consistent as compared to the speed of naming the colour of colourful strips. In case of this research and the specially developed Stroop test the person being tested were tested in terms of speed of messages processing either in mother tongue or acquired language, and in terms of interference during messages processing in mother tongue and acquired language. Hirsch theory suggesting that structures of foreign languages are located in the left hemisphere is significant for the message processing in mother tongue and in acquired language. The right hemisphere is responsible for basic expressions, while the left one is responsible for rarer terms, characteristic for those of higher language competences. Language learning is controlled by left hemisphere as an analytical and intellectual process. Natural acquisition, as unconscious process, can be dominated by right hemisphere. The acquisition process in its initial stage is controlled rather by the right hemisphere. Only at the age of 5 the left hemisphere becomes engaged. This happens because in the subsequent stages this process becomes more analytical, formal and cognitive in nature. In case of the subject group tested during the said research, the person being tested were characterised by basic knowledge of foreign language. We can thus talk about difference between language competences in case of mother tongue and acquired language. The prerequisite according to which the person being tested processed foreign terms with the use of right hemisphere as compared to the Polish terms processing with the use of left hemisphere was met.

Testing included 26 persons: 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 persons being tested 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 person being tested did not use the language on a daily basis. It should be noted that none of the person being tested 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 persons being tested were right-handed. Respondents were recruited from among WSB university 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 name 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 person being tested was to test the two parts of the test 3 times.

- The first time respondents performed the RCNb and NCWd parts in Polish version.
- The second time they performed both parts, RCNb and NCWd in English version.
- 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 1 and 2.

Table 1. *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 2. *Independent variables and their indicators*

Independent variable	**Indicator**
Performance language	• Polish • English

The results obtained 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.

2. Research 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 3.

Table 3. *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 4. Bold fonts indicate significant statistical differences.

Table 4. *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[1]	27.73		**0.000949**	**0.000103**
RCNb ENG[2]	25.04	**0.000949**		0.313950
RCNb ENG2[3]	24.27	**0.000103**	0.313950	

Statistically significant differences were observed during RCNb parts execution 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

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 5.

1 Part RCNb - Attempt 1 in Polish

2 Part RCNb - Attempt 2 in English

3 Part RCNb - Attempt 3 - repeated attempt in English

Table 5. *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 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 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 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 7.

Table 7. *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

4 Part NCWd - Attempt 1 in Polish

5 Part NCWd - Attempt 2 in English

6 Part NCWd - Attempt 3 in Polish

differences in individual measurements. Results of the post-hoc analysis are presented in Table 8. Bold fonts indicate significant statistical differences.

Table 8. *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) were made by respondents during Attempt 1 in Polish and Attempt 2 in English.

3. 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-*czerwony* 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 persons spent more time naming the color of the font in a foreign language than in the native tongue.

7 Part NCWd - Attempt 1 in Polish - number of errors

8 Part NCWd - Attempt 2 in English - number of errors

9 Part NCWd - Attempt 3 - repeated performance in Polish after the prior performance of the RCNb part in English - number of errors

The results of Attempt 3 were most intriguing when test persons being tested 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 persons being tested 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 person being tested 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

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.

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.

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.

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.

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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DEŠINIOJO IR KAIRIOJO PUSRUTULIO KALBOS APDOROJIMAS NEUROPSICHOLOGINIU ASPEKTU

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Santrauka

Straipsnyje analizuojamo tyrimo tikslas – Lenkijos studentų atveju ištirti užsienio kalbos poveikį Stroopo testo atlikimui. Tyrime dalyvavo 26 studentai: 13 moterų ir 13 vyrų nuo 19 iki 47 metų amžiaus. Pirmojoje RCNb testo (skaitant spalvas atspausdintas juodai) dalyje tyrimo dalyviai skaitė žodžius, nurodančius spalvas, parašytas juodai. Antrojoje dalyje atliekant NCWd testą (įvardijant spalvą arba žodį kai jo atspausdinimo spalva, arba žodis skiriasi) tyrimo dalyviai įvardijo spalvas, kurios buvo panaudotos - parašyti spalvą nurodantį žodį. Analizuojant tyrimo rezultatus pastebėtina, kad siejant juos su kalba atrasti reikšmingi statistiniai laiko skirtumai pirmojoje ir antrojoje testo dalyse. Greitesnis įvykdymo laikas RCNb dalyje buvo pastebėtas anglų kalbos testams. O RCNb atvejo dalyse greitesnis laikas pastebėtas kai buvo siekiama įvardyti spalvos pavadinimą lenkų kalba, anglų kalbos versijoje. Toje pačioje situacijoje buvo pastebėtas ir mažiausias klaidų kiekis.

Reikia pabrėžti, kad iki šiol europietiškoje literatūroje nebuvo naudojamas Stroopo testas siekiant apibrėžti komunikato apdorojimą gimtąją kalba ir įgyta kalba. Tai pirmas toks bandymas susijęs su kalbinio apdorojimo gebėjimo įrankiu (gimtoji kalba ir įgyta kalba), nes iki šiol Stroopo testas buvo naudojamas klinikiniams tyrimams neuropsichologinėje diagnostikoje. Tyrimų metu pasinaudota specialiu baziniu testu, parengtu vadovaujantis Stroopo testu, kuris pagal tradicinio testo blanką tyrė operatyvinę atmintį, dėmesio sutelkimo gebėjimą ir vykdymą. Tradiciniame Stroopo eksperimente tiriamieji skaitė taip pat greitai spalvas atspindinčius žodžius nepriklausomai nuo to, kokia spalva jie buvo užrašyti. Tačiau turėdami pavadinti spalvą, kokia buvo parašytas žodis, tai darė žymiai lėčiau, jeigu stimulai buvo nevienodi, o greičiau, jeigu stimulai buvo vienodi, palyginus su greičiu pavadinti spalvotų juostelių spalvas. Šio tyrimo ir specialiai parengto Stroopo testo atveju tiriamieji buvo tiriami komunikatų greičio apdorojimo gimtąja ir įgyta kalba atžvilgiu, kaip ir interferencijų komunikatų apdorojimo gimtąja ir įgyta kalba atžvilgiu. Esmine tyrimams teorija dėl komunikatų apdorojimo gimtąja ir įgyta kalba taip pat buvo Hirsch teorija, kuri sako, kad svetimos kalbos pagrindai yra dešiniajame pusrutulyje. Dešinysis pusrutulis specializuojasi pagrindinėmis sąvokomis, tuo tarpu kairysis - retesnėje terminologijoje, būdinga asmenims turintiems aukštesnę kalbos kompetenciją. Kalbos mokymasis kontroliuojamas kairiojo pusrutulio, kaip analitinis ir intelektualusis procesas. Natūralus pasisavinimas kaip nesąmoningas procesas gali būti dominuo-

jantis dešiniajame pusrutulyje. Pasisavinimo procesas pradiniame etape kontroliuojamas labiau dešiniojo pusrutulio. Tik būnant penkių metų amžiaus įsitraukia kairysis pusrutulis. Šis procesas kitose stadijoje yra labiau analitinis, oficialus ir pažintinis. Tirtų asmenų grupės atveju šių tyrimų metu asmenys pasižymėjo pagrindiniu įgytos kalbos žinojimu. Taigi buvo skirtumas tarp kalbinių gimtosios ir įgytos kalbos kompetencijų. Išpildyta prielaida, pagal kurią tiriami asmenys apdorojo svetimos kalbos žodžius skirtingai nuo kairiojo pusrutulio apdorojamų žodžių lenkų kalba.

Reikšminiai žodžiai: *Stroopo testas, neuronų apdorojimas užsienio kalba, trikdžiai, įtikinėjimo klaidos, verbalinė atmintis.*

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