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Original article ■

Gender Differences in Prosodic Characteristics of Speech in the Task of Serial Subtracting of Sevens

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SUMMARY

Significant differences in speech between genders are contained in nonsegmental correlates, i.e. in the prosody and paralinguistics. Pronunciation differences between genders are more numerous than those in grammatical form. This study aims to detect temporal prosodic patterns and investigate gender differences in performing serial sevens subtraction (SSS). One hundred students of medicine (equal number of males and females) voluntarily participated in the investigation. SSS was performed by asking the participant to perform mental arithmetic consisting of repeatedly subtractions of sevens, beginning from one thousand. The students had to pronounce aloud and simultaneously write the results for five minutes. The original program for the analysis of digital signals (ADS) converted the speech signal samples into digital data. MANOVA showed significant gender differences for a group of characteristics of the SSS test: F (11, 75)=4.06, p=0.000. The number of samples per each minute and the total number of samples during five minutes was higher in males compared to females. The average length of articulation of three-digit numbers, average length of articulation and length of pauses between the linguistic units, as well as between the samples, was shorter in males for each of these five minutes and for the „average“ minute. The maximum intensity of speech was higher in males for each of the five minutes. Average duration of mispronunciations, with end results being correct, was longer in women in the first, second, and fourth minute, as well as for the „average“ minute. A conclusion may be drawn that shorter utterances and pauses in men suggest the advantage on the part of men in SSS task, and not greater verbal fluency in general in men.

Key words: **gender differences, serial seven subtraction task, prosody**

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INTRODUCTION

Gender differences in cognitive functions

Numerous factors, such as genetic, effects of gonadal hormones, genomic and nongenomic action of steroids, as well as environmental factors, determine numerous gender differences in cognitive functions (1, 2). It is believed that the traditional division of jobs and work in general into female and male jobs has contributed to gender differences at the level of the brain. The functional revolution of the Broca's area for speech and the angular gyrus has led to female superiority in grammatically (temporal-sequential) rich vocabulary, and the development of visual-spatial skills has led to male superiority in that area (3, 4). Male students are more successful than female ones in the tasks requiring spatial abilities, „shortcuts", or multiple routes to solution, but not in the mathematical problems the resolution of which requires verbal abilities (5). Female students show greater interference in manual-verbal tasks, in finger tapping, and with tasks presented aurally in contrast to visual presentation. Male students have been better in the mental rotation task (6). The lateralization index has shown that in men language is primarily lateralized to the left, as well as in one half of women, while the other half of women have had bilateral representation of the language function (7).

The differences between genders in mathematical tasks have not been spotted in younger populations (elementary schools), but they have been identified in secondary schools and colleges. Men have been more numerous at both high and low distribution tails (8). Literature data indicate female superiority in different memory tasks, which can also be explained by „verbal skills". However, in memory tasks where verbal strategies cannot be utilized, female superiority was not found. Special visualization, ability of two- and three-dimensional stimulus rotation (belonging to abstract reasoning required in mathematical problems), the male superiority was detected. It was also established that these gender differences are culture-independent.

The average steady state metabolism, calculated for the whole brain, does not differ between men and women. While men have a higher relative metabolism in the lateral and ventromedial portions of the temporal lobe, a relatively lower metabolism has been observed in the medial and posterior part of the cingulate gyrus. Men and women are almost identical in the topographical distribution of lateral asymmetry, and in only three regions gender-related differences have been found (orbitofrontal, posterior cingulate gyrus, and posterior corpus callosum), with relatively higher metabolism in women (9). Using functional magnetic resonance imaging (10), it was found that the activity of the inferior frontal cortex during a phonological task was lateralized in the left hemisphere in men, being bilateral in women, leading to a possible conclusion that lateralization of functions was more pronounced in men compared to women. A semantic task activates the same areas as a rhyming task - the upper and middle temporal gyrus, traditional language regions. A task requiring orthographic processing activates the extrastriate areas. Women produce more words than men in phonological fluency tests. Women are superior in the Digit-Symbol (WAIS) test. The performance of the test requires integration of many different abilities: memory, motor maintenance, attention maintenance, response speed, and visuomotor coordination. It has been suggested that the skill of verbal signal encoding is a factor contributing to the observed superiority of women.

Men and women see the world in different ways. Men are superior in mental rotation of three-dimensional objects, while women are more successful in the recognition of emotions of photographed people. It seems that male brain is more lateralized than female brain for both verbal and nonverbal functions. Some data demonstrated greater lateralization in women in the tasks requiring oral reports and motor performance. Women are superior in reading and writing, and men in science and mathematics. Although the average gender differences narrow for science and mathematics, the differences in reading and writing are still the same. Some authors pointed out that genders differed in the dynamic aspects of cerebral functional asymmetry and that temporal dimension had to be considered, too.

Gender differences in speech

Speech production is one of the several functions localized in the left hemisphere (Broca's area). It seems probable that this system is involved in mental repetition, where speech belongs too; repetition „refreshes" the conscious access to momentary memory. However, voluntary control is generally associated more with the frontal cortex, so that this functional system may involve both frontal areas and Broca's area. In view of their verbal fluency, women show greater grammatical competence and sentence complexity, and less speech disorders (all types) even since early ages.

Especially significant gender differences are observed in nonsegmental correlates, i.e. in prosody and paralinguistics. Pronunciation-related gender differences are much greater than those in grammatical forms. In a study of relationship of spectral and prosodic signs (11), it was established that the dependence of pitch and duration differed in men and women uttering the sentences in affirmative and inquisitive intonation. Tempo of speech, pitch range, and pitch steepness differ between the genders. Texts developed for actual measurement of verbal speed have shown that more than 185 words in a minute is a high speed for normal speech situations, and less than 140 words in a minute is a low speed. Length of sounds and words varies with emotional attitudes. Relatively short, even „staccato" tones are used to express anger, and prolonged ones to express love.

Good speakers tend to prolong (on the average) their words compared to poor speakers. Poor speakers consistently tend to use staccato speech.

Brain and mathematics

The answer to the question how much is 2 plus 37 is probably the result of the left angular gyrus (AG) function. The area has a role in the rapid recall of the fact, with possible involvement in the mapping of the quantity of Arabic numerals. The intraparietal sulcus (IPS) in the left hemisphere has a role in calculations and seems to have a greater role in the comparison of actual, symbolic numerals, such as 3 and 8, compared to non-symbolic numerals (such as object collections). The right intraparietal sulcus (IPS) is the area active in calculations and comparisons of two sets of objects. It has been shown that it is less active in children with developmental dyscalculia, a learning disorder which affects the learning of arithmetic. Dyscalculia in children may be the consequence of disturbed word recall, working memory problems, executive functions, or visuo-spatial abilities (12).

According to the triple code model (13), adding is associated with the activity of the perisylvian region, while assessment skills and geometric evidence are associated with bilateral activity of the inferior parietal lobe. Interestingly, lesions along the left perisylvian region of the left hemisphere, the region responsible for linguistic data processing (reading, written language), commonly lead to the inability to identify or name a numeral.

In the study of the activity, volume, and density of certain parts of the brain in solving mental arithmetic tasks requiring adding and subtracting of three numbers (14), a higher activity of dorsal stream in the right intraparietal sulcus was found (important for numerical cognition), as well as a higher activity of ventral stream in the right lingual and parahypocampal gyrus in males. A reverse pattern was seen in women. There were no brain areas with higher activity in women compared to men, but there were neither the areas with higher structural density or regional volume in men compared to women. There are data about higher density of layers II and IV (but not III, V, and VI) of the auditory association cortex in women compared to men.

The study of neuropsychological functions of patients with massive lesions involving almost the entire posterior half of the left hemisphere suggests the existence of two different streams of numerical processing in normal subjects: one enabling correct number representation, memory, and calculation using symbolical notation, and the other enabling approximative calculation using analogical representation of quantity. Experiments with normal subjects suggest the existence of analogical representation for numerical quantities. After the translation from Arabic numerals, the numbers would be mentally represented in the same way as physical quantities - as sizes or weights (analog encoding). The subject functions in the same way whether he has to choose a bigger out of two objects, or a higher number out of two numbers. This example suggested the existence of a limited ability to process numbers in the right hemisphere, which was termed „arithmetic intuition“. There is the question whether the competence for solving mathematical problems is the result of a general learning ability, or the result of special neuron circles specialized for numerical processing, being at least partly associated with the left inferior parietal lobe. Ample evidence suggest that the acquisition of precise arithmetic takes place in a specific language format, making up the networks involved in word processing, while approximative arithmetic is language-independent, based on the feeling of numerical quantities, driving bilateral fields of the parietal lobes involved in visuo-spatial processing (15).

Comparison of the results of the patients with lesions of the left and right hemisphere shows that those with the left hemisphere lesions have a significantly higher number of errors in reading numerals and arithmetic signs, counting backwards, and execution of successive operations. Difficulties seen with successive operations in patients with left retrorolandic lesions can be explained by the need of good verbal memory for the execution of the task. Working memory is involved in the dynamic aspects of real-time processing in the tasks with serial operations. That is why executive functions are investigated in the experiments involving complex tasks of spatial transformation and mental arithmetic, with subjects executing sequences of mental operations in close succession. In such tasks, the working memory serves to connect cognitive operations and coordinate these processes with other operations on relevant information. Coordination is required also for the selection and „acceptance“ of a cognitive procedure, in order to execute it and link it with ongoing information and objectives. The functions of visual working memory involve neuronal networks of nerve structures, such as extrastriate and prefrontal cortex, and parts of medio-basal temporal lobes. Speech takes precedence over writing - writing represents a higher level of verbal expression, the most difficult and most complex form of voluntary and conscious language performance.

The students with a higher level of mathematical anxiety are worse in solving mathematical problems than those with a lower level of mathematical anxiety at all levels of solving. The central executive system, inhibiting negative distracters, is commonly inefficient in anxious subjects (frontal cingulum). This would open the way to concerns and negative thoughts, overloading the system (16).

Serial subtraction of sevens

The tests of vigilance, such as sequential presentation of stimuli (numbers, letters), aim to investigate the ability to maintain attention. The most commonly used test in the assessment of vigilance, or close, sustained attention, is the test of continued execution. The test of serial subtracting of sevens (SSS), used in our study, belongs to the group of mental observation tests. The statistical data related to the SSS test are limited, usually as a part of mental status studies, presented by psychiatrists, neurologists, and others (17). The experiments with prolonged serial calculation are the most convenient method to investigate the defects in the execution of basic calculations in lesions of the frontal areas. Vigilance test can be further complicated by the demand that the subject seeks two or more stimuli or associated ideas simultaneously, in alternation, or subsequently, in multiple vigilance behavior. The capacity for double or multiple vigilance is one of the first to be disturbed with brain damage or under stress (18, 19) and the disorder may present as a difficulty observing one thing, while the other is executed. Calculation skill is an especially complex cognitive ability and a complex functional system, requiring integrated activity of multiple processes. Task execution takes place in several processing stages: retrieval of the arithmetic operation from long-term memory, storage of results and processing in working memory, and sequential execution of arithmetic operations.

Principally, the test of counting measures the efficacy of vigilance. The instructions for subtraction test require a backward pattern transposition. The requirement of the test is a demanding activity engaging the working memory. The ability to reverse the numbers is „probably a characteristic of normal cognitive function and language processing", related to the normal temporal-order brain function (20). The data showed that patients with damaged right hemisphere, with visual field defects performed worse in the test than those with the same damage and without such defects. Low scores reflected disturbed concentration and mental searching. Based on the study data, Bender concluded that the ability to reverse a sequence of letters, numbers and words was a characteristic of normal thinking and language processing.

This study aimed to detect temporal prosodic signs/markers and to investigate gender differences in solving the SSS test. The purpose of the study was to get a better insight into the understanding of normal prosody and to establish cognitive differences in solving this test of sustained attention, mental surveillance, and working memory.

EXAMINEES AND METHODS

Subjects

The studied sample consisted of 100 second- and third- year students of the Faculty of Medicine in Niš. The sample was gender-balanced. The examinees were medical students, with Serbian as their mother language.

Methods

In order to assess the function of speech, the subjects had to sit a modified version of the Lottig's test of useful consciousness - a serial subtraction of sevens. They were asked to count backwards from 1.000 by sevens, expressing the results aloud and writing it down at the same time, for 5 minutes. The original program for digital signal analysis (ADS), in the process of sampling, transformed the samples of speech signal into digital recordings (21, 22). The program was devised to be interactive - we were always able to see the graphical representation of a signal and hear the sampled segment via sound card. The principle of selection of a segment to be processed was performed using two vertical cursors, defining the start and end of a selected speech signal, i.e. singling out words from the ambient noise. The duration of individual articulations of hundreds, tens, and units was thus determined, as well as the duration of pauses within three-digit numbers and between them, for each correctly spoken three-digit number. Based on these data, we calculated an average duration of speech (TS), average duration of articulation of three-digit numbers (DS), duration of pauses within three-digit numbers (PS), and between three-digit numbers (PU) for correctly spoken three-digit numbers, and the ratio (quotient) of TS and PS represented the measure of relationship of speech and pause durations (TPK). The average (TSI) and maximum (TSM) intensity of pronunciation was obtained in a similar way, as the average of all correct pronunciations for the period of five minutes.

Incorrect results in subtraction of sevens were analyzed separately, calculating the average duration of period, with subjects blinded to the incorrect answers, during the test period of five minutes, and the average value was calculated afterwards, marked as the duration of „unuseful consciousness" (NS) per average minute. All incorrect responses in SSS, regardless of their contents, were registered separately. A great diversity of these responses, such as repetitions of previous responses, starting of responses and paralinguistic responses were analyzed through the variable of average duration of response „errors" per minute (POCAS). Percentual ratios of the duration of „errors" to duration of pauses (POCP1) and to duration of responses (POCP2) were calculated.

Results

MANOVA showed significant gender differences for the group of characteristics in the test of serial subtraction of sevens: F (11, 75)=4.06, 0.000.

Our univariate analysis (Table 1) demonstrated gender differences for the following SSS test parameters: duration of speech (TS), duration of pauses within three-digit numbers (PS) and between three-digit numbers (PU), and duration of „errors" (NS). Gender-related differences were not observed for the parameters derived from these measures, such as duration of speech and pause (TPK), and the percentual ratio of duration of errors to duration of pauses (POCP1), or to duration of speech (POCP2). Moreover, we did not find gender differences for the duration of speech with incorrect results (NS).

Gender-related comparisons in the SSS test for independent samples

The number of samples per each minute separately, as well as the total number of samples for all five minutes, was higher for males. Average duration of speech of three-digit numbers, average duration of speech and duration of pauses between linguistic units, as well as between samples, was shorter in men for each of these five minutes, as well as for the „average minute“. Maximum intensity of speech was higher in men for each of these five minutes. Average duration of incorrect speeches, with correct end results, was longer in women in the first, second, and fourth minute, as well as for the „average minute“ (Table 2).

The set of variables related to the SSS task showed a significant effect of gender. The effect of gender is shown for the set of SSS variables that does not contain incorrect answers nor errors: F(9.55)=2.72, p=0.011.

Male gender was characterized by a higher maximum intensity of speech (TSM) compared to female gender. We were unable to demonstrate any differences in the average speech intensity (TSI) between the genders (Table 3).

Table 1. *Values of F ratio (F) and significance of differences (p) by gender for SSS test variables obtained by univariate analysis of variance*

Variables	F	P
PU	6.799	.011
DS	11.71	.001
PS	7.94	.006
TS	13.69	.000
POCAS	8.006	.006
NS	.25	n.s.
TSI	.67	n.s.
TSM	2.85	.095
TPK	1.458	n.s.
POCP1	.20	n.s.
POCP2	1.507	n.s.

Table 2. *Values of arithmetic means (AM) and standard deviations (SD) of duration of speech and pauses expressed in seconds in the SSS test, t-test (t), and significance of differences (p) for female (f) and male (m) gender*

Gender / Variable	F		M			
	AM	SD	AM	SD	t	p
PU	1.539	1.089	1.012	.506	3.10	.002
DS	4.844	1.536	3.829	1.01	3.90	.000
PS	1.006	.545	.710	.327	3.29	.001
TS	.786	.113	.701	.090	4.15	.000
NS	2.982	3.644	2.944	4.327	.05	n.s.
POCAS	.393	.116	.326	.102	2.81	.006

Table 3. *Values of arithmetic means (AM) and standard deviations (SD) of average (TSI) and maximum (TSM) intensity of speech in the SSS test, t-test (t), and significance of differences (p) for female (f) and male (m) gender*

Gender / Variable	F		M			
	AM	**SD**	**AM**	**SD**	**t**	**p**
TSI	9.47	5.48	10.88	6.48	-1.17	n.s.
TSM	65.44	32.68	80.58	34.74	-2.24	.027

DISCUSSION

Measurement of the duration of pauses in speech within and between three-digit numbers, and duration of speech in SSS testing, enables the assessment of cognitive functioning. Since the SSS test requires a special type of cognitive effort, the differences in fluency found between the genders could be ascribed to the difference in success in solving this test. It could be concluded that shorter speeches and pauses in men, characteristic in both studied situations, suggest the advantage on the part of men in this task, and not better fluency in general in men.

Investigations have so far demonstrated that women are more prone to mistakes in solving the SSS test. The data of this study showed a significant difference between genders for 6 out of 11 different characteristics studied in the SSS task. The characteristics for which significant gender differences were not found are the period of „unuseful“ consciousness and percentual ratio of duration of „error“ to duration to speech. Our study demonstrated that the use of SSS test involved various errors, which could be described as a disintegration of inner „quasi-spatial“ syntheses as the consequence of disturbances in the parieto-occipital areas of the dominant left hemisphere, and as a stereotype inertia due to disturbed frontal areas.

Hemispheric specialization, that has been thought of as an „intrinsic“ (biologic) difference in cerebral functioning, can be modified later on in life as well by a certain amount of learning experience. The findings from the studies of soroban experts suggest that the synergy of the left and right hemisphere increases cognitive functioning. These experts demonstrate better calculation ability compared to control subjects (although they are university students), since they use the right as well as the left hemisphere, while „ordinary“ people rely on the left hemisphere only.

Arithmetic skills are associated with the left arm dexterity, suggesting that arithmetic abilities are specifically dependent on the right hemisphere, at least in elementary school. The effect also applies to intelligence and test scores in English language (23).

Male students are more successful than their female peers in using adequate strategies in problem-solving - flexible strategies are probably the reason of gender differences in task solving (5). Reaction time is the function of number of elements and number of transformations present. The proportion of error is determined by the complexity of transformations of an analog problem. The patients with lesions of the parieto-occipital areas of the dominant left hemisphere have difficulties analyzing not only the obvious, but also symbolic relationships. These patients have difficulties in understanding of relatively complex logical-grammatical structures. A disorder of the inner „quasi-spatial“ syntheses is expressed in the disintegration of calculation operations. Calculation operations (of the „matrix calculation“ type) in their early stages are non-differential in character, and later transform into actions relying on intrinsic spatial schemes. For them to be resolved, it is always necessary that simultaneous syntheses are preserved, their being built on the same principle as spatial operations.

Several models can be useful to explain and understand mathematical operations. One of these is the Baddeley's model of working memory (24), involving appropriate cortical regions. The central executive component, according to this model, directs cognitive resources towards other memory systems, focuses, changes, and maintains attention, and inhibits negative distracters, modulating anxiety and regulating emotional stress. It depends on the interconnected phonological loop and visuo-spatial sketch pad. The phonological loop is an inner voice, essential for verbal recall of information, with 7 ± 2 item capacity. It is used for automatic recall of information stored in a verbal format, providing the recall of mathematical facts and writing down dictated numbers. Phonological storage stores acoustic information for up to 2 seconds without recall. The sub-vocal recall system is an inner voice which serves to refresh information in the phonological storage space. It is connected to the visuo-spatial sketch pad, an inner eye of the mind that provides visual images, mental rotation, and facilitates mental mathematical skills, relating the skills and geometry rules.

Executive functions and mathematic abilities are enabled by the following neuronal circuits: dorsolateral circuit, the primary projections of which are directed towards the basal ganglia and, helps in organizing a behavioral response in solving complex tasks (25); orbitofrontal cortex mediates in empathic, polite, and socially acceptable behavior. It is amply connected to the limbic regions, supporting the modulation in solving affective problems, judgment, and interaction of social skills. Anterior cingulate cortex provides for a multitude of functions connecting attention capacities with a given cognitive task. The region helps the brain to divert its conscious energy towards either the inner cognitive events, or towards external incoming stimuli.

The analysis of gender differences in the task of local vs. global processing showed that the effect of interference was more explicit in women (26). If we take into account that interference results in longer time to react to incompatible stimuli and that it represents the measure with which a subject can alter the perceptual set to adjust to changeable demands, we can conclude that men have less difficulties in altering the perceptual set, i.e. that they have more flexible attention. It is possible that different types of attention are involved. Women are prone to autoplastic ways, taking the object as a whole, while men are prone to alloplastic ways, analyzing the object in parts. Additional analysis with other methods, such as fMRI, would be useful in and investigating neurocognitive functioning (27) and detecting gender differences in verbal and nonverbal communication, taking into account their significance for successful communication (28, 29).

CONCLUSION

In spite of the stereotypic belief that men are more successful than women in mathematics, the findings concerning gender differences are confounding, some studies have found male superiority, while others found the opposite (30, 31). Men are more successful in mathematics in a group of high achievers, and among gifted children and college students (32), while women are more successful towards the low distribution tail (33). Our study demonstrated superiority on the part of men in solving the serial sevens subtraction task. Male students had shorter utterances, shorter pauses within and between three-digit numbers, as well as shorter duration of errors, compared to their female counterparts. The advantage was probably based on a higher degree of flexibility of attention/vigilance found in male students.

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POLNE RAZLIKE U PROZODIJSKIM KARAKTERISTIKAMA GOVORA TOKOM REŠAVANJA ZADATKA SERIJSKOG ODUZIMANJA SEDMICA

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Sažetak

Značajne razlike govora među polovima su u nesegmentalnim korelatima, tj. u prozodiji i paralingvistici. Razlike u izgovoru muškaraca i žena su mnogo brojnije nego razlike u gramatičkoj formi.

Cilj ovog istraživanja bio je da se detektuju vremenski prozodični obrasci i istraže polne razlike pri rešavanju zadatka serijskog oduzimanja sedmica (SSS). U istraživanju je dobrovoljno učestvovalo 100 studenata medicine (podjednak broj muškog i ženskog pola).

Zadatak ispitanika je bio da se počev od broja 1000 sukcesivno oduzima po sedam, glasno izgovarajući rezultat, uz istovremeno ispisivanje brojeva, u vremenskom trajanju od 5 minuta. Originalan program za analizu digitalnih signala (ADS) uzorke govornog signala pretvara u digitalni zapis. MANOVA je pokazala značajne razlike po polu za grupu obeležja testa SSS: $F (11, 75)=4{,}06$, $p=0{,}000$. Broj uzoraka za svaki minut posebno, kao i ukupan broj uzoraka za svih pet minuta veći je za muški nego za ženski pol. Prosečna dužina izgovora trocifrenog broja, prosečna dužina izgovora i prosečno trajanje pauze između lingvističkih jedinica, kao i između uzoraka, kraće je za muški pol za svaki od pet minuta, kao i za „prosečan" minut. Maksimalni intenzitet izgovora veći je za muški pol, za svih pet minuta. Prosečno trajanje pogrešnih izgovora, kada je krajnji rezultat tačan, duže je za ženski nego za muški pol i to u prvoj, drugoj i četvrtoj minuti, kao i za prosečni minut.

Može se zaključiti da kraće trajanje izgovora i pauza osoba muškog pola govori o prednosti ovog pola pri rešavanju SSS zadatka, a ne o izraženijoj verbalnoj fluentnosti uopšte za muški pol.

Ključne reči: **polne razlike, serijsko oduzimanje sedmica, prozodija**