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A Model-Based Approach to Apraxia in Multiple Sclerosis

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ABSTRACT

Introduction: *Multiple sclerosis is a disease demyelinating disease. Symptomology is diverse, and motor symptoms are strongly present. That is the reason why research of limb apraxia in people with MS started recently. The presence of limb apraxia in some individuals was found, however, the characteristics of apraxia have not been described till date. Therefore, the aim of this study is to describe the characteristics of apraxia in people with MS using Roy's conceptual-production model of apraxia.* ***Methods:*** *To test this, a sample of 60 people was formed, 30 with MS (age 51.34; SD=7.70 years) and 30 without (average age 50.30; SD=10.47 years), who belonged to the control group. The instruments used were the questionnaire for collecting demographic data and basic disease data from participants as well as the Waterloo-Sunnybrook apraxia battery for assessing the apraxia presence.* ***Results:*** *Limb apraxia was not present for the majority of people. On the basis of the obtained scores, it was found that the following patterns of the apraxia were most commonly present as P+DI-CI-ID-; P-DI-CI-ID-; P+DI+CI-ID+.* ***Conclusion:*** *Results indicate that in most people with MS, there is apraxia which, at its base, has damage at the level of the production system, with the problems of dual processing of information and slow processing, as well as problems in attention control. In a smaller number of people with MS, apraxia is characterized by impairment at the level of the sensory/perceptive system, as well as the impairment to both the conceptual and the production system.*

Keywords: Limb apraxia, Multiple sclerosis, Voluntary motor action, Conceptual-production model of apraxia, Apraxia patterns

INTRODUCTION

Multiple sclerosis (sclerosis multiplex) is a chronic inflammatory disease of the central nervous system (CNS), with the basic pathophysiological property of the destruction of myelin-demyelination [1]. Since in MS there are not only motor but also cognitive deficiencies, it is expected that limb apraxia might be present in MS. Since neuromotor signs are dominant, research of the cognitive aspect of motor functioning has been almost neglected up to now. Recently, 2 studies have confirmed the presence of limb apraxia in MS [2,3].

Since limb apraxia is present in people with MS, the question arises as to the characteristics or patterns of apraxia in people with MS. To determine this, we used Roy's model of conceptual-production systems of voluntary motor action. Roy's model is a product of a cognitive neuropsychological approach. This model anticipates the existence of 3 systems: the sensory/perceptive system, the conceptual system, and the production system. The role of the sensory/perceptive system is the analysis of input information. The conceptual system uses knowledge of action and objects as a base for carrying out the movement. The production system includes cognitive and sensorimotor processes that are responsible for organizing and controlling the movement [4,5].

Impairment of each of these systems can lead to some specific deficits in motor activity. If a sensory/perceptive system is impaired, the ability to recognize the tools and gestures can be jeopardized. The person will not be able to process visual information about gestures or tools in relation to their function.

If the conceptual system is impaired, 2 types of knowledge are jeopardized: knowledge about tool and/or object, or knowledge about action. Knowledge about action means that a person knows how to use tools and objects in the sense of the interaction of movement with a tool. Knowledge of action also means knowing how to perform a movement that does not require the use of tools (non-transitory representative). When tool knowledge is impaired, it is possible that a person uses some tools for the wrong purposes. When the knowledge of action is impaired, the person has problems

in identifying gestures or gestural errors, and therefore cannot assess the quality of the other's or his own movements.

Difficulties at the level of selecting responses, generating representations, working memory or spatial and temporal organization of the movement, including the posture and orientation of the hand, the coordination and the plane of movement, are classified as damage of the production system [6]. Roy considers that it is possible to determine exactly the level of impairment by comparing achievements on tasks of the pantomime, delayed imitation of the movement and concurrent imitation of the movement [5]. Pantomime tasks usually involve performing a movement on a verbal cue. Generating of gestures, at that time, is done from secondary memory, which requires the inclusion of all levels. On the other hand, imitation of the movement does not require data from secondary memory but requires an analysis of the characteristics of the movements of the person being imitated. When it comes to concurrent imitation, only the ability to program responses and control is needed. If imitation is delayed, it is necessary to store information about the movement that is imitated in the working memory so that the movement to be imitated is memorized and then executed.

Considering that achievement comparisons on these tasks can give insight into the specificity of the conceptual and production system, Roy has envisioned 8 achievement patterns within his model [5]. Patterns were formed in relation to the level of achievement in the tasks of the pantomime (P), concurrent imitation (CI), delayed imitation (DI), and gesture identification (ID).

Impairment of the sensory/perceptive system implies a reduced ability to recognize gestures and tools, which is why the ability of delayed and concurrent imitation is damaged. In this case, the pantomime is preserved because it relies on memory as opposed to the imitation of the movement. Within Roy's model, this is the first pattern of achievement (Pattern 1: P+DI-CI-ID-). Impairment to this system affects not only the reduction of the possibility of analyzing the spatiotemporal characteristics of the movement but also the organization and control of the movement, which is especially pronounced in the imitation of the movement.

Impairment to the conceptual system should produce a poor performance on recognition tasks and pantomime. Imitation of the movements should be preserved. Within Roy's model, this pattern is number 2 (Pattern 2: P-DI+CI+ID-). This form of achievement is often referred to as ideational apraxia within various researches.

In the case of the impaired production system, several forms of achievement are defined. The connection between the sensory/perceptive and production system can be impaired [7]. When communication between the auditory/verbal and production system is impaired, a person can perform a pantomime only when an instruction is not of an auditive nature. If a tool is visually presented to a person, or if it is put into her hands before doing the pantomime, it will enable the proper performance of the pantomime. Communication impairment between the sensory/perceptive and production system within the model is expressed in pattern 3 (Pattern 3: P-DI+CI+ID+). In this case, a person possesses the knowledge needed to perform the action but simply does not know how to transfer that knowledge into action.

Impairment to working memory within the production system can be found in 2 patterns of achievement (Pattern 4: P+DI-CI+ID+; Pattern 5: P-DI-CI+ID+). Gesture identification and tool knowledge are preserved. According to Roy's model, presentations are generated at the early levels of the production system and are related to the pantomime [5]. They are encoded by visual information on the movement of the person to be imitated, after which they are processed and retained in the working memory. A specific deficiency in the ability to encode visual gesture information into the working memory results in the appearance of the pattern 4. Persons in whom this type of impairment is present can generate the performances needed to execute the pantomime and analyze real-time gesture information, but cannot encode the visual gesture information in working memory. There is a possibility that people with memory impairment are not able to retain the generated performances necessary for the production of the pantomime, nor are they able to encode the visual information about the gesture in the working memory but are still able to perform concurrent imitation. In this case, the pattern 5 is present.

The impairment to later levels of the production system can be seen in 2 patterns (Pattern 6: P+DI-CI-ID+; Pattern 7: P-DI-CI-ID+). Persons in whom pattern 6 is present are able to analyze visual gesture information. Achievements on tasks of imitation are low because they are not able to use preserved information in order to organize and control the movement. When the pattern 7 is present, people know how a gesture should look, although they are not capable of

performing it either as a pantomime or as an imitation. This pattern corresponds to what most researchers in this field call ideomotor apraxia. Pattern 7 refers to the inability to adequately organize response and control. Despite preserved knowledge, persons within whom this pattern is present should have almost identical poor achievements in both tasks of delayed imitation and tasks of the concurrent imitation of the movement. This would be an additional confirmation that the damage is related to the later level of the production system.

Multiple impairments imply that both conceptual and production systems are damaged. The 8th achievement pattern is such that achievements on all tasks are poor (Pattern 8: P-DI-CI-ID-). The ability to recognize actions and tools, as well as tasks of pantomime, delayed and concurrent imitation are impaired in the persons in whom this form is present. This is also the most difficult form of apraxia.

There is no research in which Roy's model of the conceptual-production systems is applied to the population of MS patients. It is, therefore, necessary to see if Roy's model as a whole is applicable to the population of MS patients. Since MS is a demyelinating disease, it is expected that the flow of information through the nervous system is slower, and therefore the control of the action is compromised. One of the symptoms that people with MS have is vision problems, which further demonstrates the justification of our expectations. The only pattern that Roy defined in his model, which includes the existence of damage at the level of motor control, is pattern 7. It is therefore expected that the largest number of participants in the research has poor performance on tasks so that they reflect the pattern 7. Although this is our expectation, we do not exclude the presence of other forms of apraxia. Therefore, the aim of this research is to determine which forms of limb apraxia are most dominant in people with MS.

MATERIALS AND METHODS

Prior to the selection of participants in the sample, the criteria for which this selection was conducted were created. These criteria imply that the sample will consist of 60 persons of both genders, 18 to 65 years of age. All participants who participated in the testing had to read, understand and sign a form that confirms the consent to participate in the research. Two groups, similar to the number of participants, were formed, and those were experimental and control groups. The experimental group consists of 30 persons of both genders who are diagnosed with multiple sclerosis according to McDonald's diagnostic criteria [8]. The experimental group will consist of persons who are members of the Multiple Sclerosis Society of Serbia. The members of the experimental group were not persons who had associated diseases that could have an impact on the scores on measuring instruments. The control group consisted of 30 healthy participants of both genders. Pregnant women were neither in the control group, nor the experimental group. It was anticipated that the demographic characteristics (gender, age, educational status) of the control group and experimental group will be uniform.

The research was conducted in the Multiple Sclerosis Society of Serbia (New Belgrade, Aranđelovac) and in Institution for care and social protection of adults with disabilities in Belgrade. The research was approved by the University in Belgrade committee.

Instruments

For the research purposes, the following instruments were used:

Questionnaire for collecting demographic data and basic disease data from participants: Questionnaire contained demographic data, order numbers, gender, date of birth, education level, professional status, marital status. Also instrument was containing information about the disease, it contains the information about multiple sclerosis, like the type of MS, the year in which the participant was diagnosed with MS, the duration of MS, the presence of symptoms of the disease, the time since the last exacerbation, the presence of other diseases, etc.

Adapted Waterloo-Sunnybrook apraxia battery: The original battery of tests involves testing of 3 types of gestures: transitive, intransitive and non-representative [9,10]. It also contains scales to assess the conceptual knowledge of transitive gestures, as well as the scale of gesture production (pantomime, concurrent imitation, delayed imitation, use of the right tools). The scoring of production tasks can be carried out in 5 dimensions: location, hand position, action, orientation, the plane of movement. Each of the dimensions includes the rating: 0 (incorrect), 1 (distortion) and 2 (correct). The internal reliability of the battery, when it is evaluated by different evaluators, is set to a minimum of 80%, while the test-retest reliability has not been determined. The validity of the battery is also not determined, as the authors state, because there are currently no instruments for assessing the apraxia with which to compare. Stamenova

states that certain scales of this battery exhibit a high degree of validity and are comparable to some neuropsychological tests [11]. This battery is used to estimate apraxia and verify the theoretical settings of the conceptual-production model of the motor activity by Erik Roy, which additionally gives the battery its validity. The battery is adapted for the purposes of our research so that it can be used with a computer program developed for the needs of acquisition, analysis, and partial processing of data. The above adjustments related to the modification of the method of issuing instructions that are now incorporated into the computer program. In the quality evaluation protocol, the assessment of the presence of content errors (perseveration, relational, non-relation, part of the body as an object, etc.) has also been included. These changes are partially aligned with the evaluation method which was carried out in previous research by researchers from the Department of Somatopedia, Faculty of Defectology, University of Belgrade and the research of so-called Heilman's group of researchers. With these adaptations, a new instrument named Belgrade apraxia battery was created.

Procedure

After collecting the necessary approvals, the testing was conducted. Based on the database of the Multiple Sclerosis Society of Serbia and through an interview with participants, the questionnaires for the collection of demographic data and basic disease data from the participants were filled. Then, testing was carried out using an adapted Waterloo-Sunnybrook apraxia battery for apraxia assessment. After that, the scores on the scales of recognition, pantomime, delayed imitation of the movement, and the concurrent imitation of the movement of adapted Waterloo-Sunnybrook apraxia battery was calculated. The deviations in these scores of the experimental group were measured in relation to the control group. In that manner, the z-scores for the experimental group were calculated. If the deviation in the achievements from the control group would be greater than -2 SD (for example, -3, -4), on that scale, apart from the abbreviation that marks it, the minus sign (-) would be marked, while a plus sign (+) would be marked for minor deviation. In this way, each participant would get his own pattern of achievement. As we have stated, achievement patterns define whether the apraxia is characterized by damage at the level of the sensory/perceptual, conceptual or production system. This way, the dominant apraxia patterns for people with MS will be determined.

RESULTS

Sample Description

The control group consisted of 30 people from a typical population of the average age of 50.30 (SD=10.47) years. Within the group, the number of male and female participants is the same. The experimental group consisted of participants suffering from multiple sclerosis of the average age of 51.34 (SD=7.70) years, 14 (46.70%) men and 16 (53.30%) women. In the experimental group of participants, multiple sclerosis was diagnosed when they were 34.28 (SD=8.74) years old on average. People had symptoms of the disease on average 5.43 years before the illness was diagnosed, at least 3 months, and at most 35 years. The majority of participants suffer from a relapse-remitting (33.33%) and primary progressive (33.33%) form of MS. The average time since the last exacerbation was 4.49 years (SD=9.91), a minimum of 1-month and a maximum of 11 years. All participants have all typical symptoms of the disease. Most often, fatigue and walking disturbances occur, and rarest are pain and depression. Most of the participants, 93.40% were employed before the onset of the disease (Table 1).

Table 1 Characteristics of the health condition of participants with multiple sclerosis

Characteristics of the disease	N (%)
Age when MS was diagnosed	34.25 (8.74%)
The time of the presence of symptoms before the diagnosis of the disease	5.43 (8.99%)
Type of MS	
Relapse-remitting	10 (33.30%)
Primary progressive	10 (33.30%)
Secondary progressive	2 (6.70%)
Benign	1 (3.30%)
Unknown	7 (23.30%)
Time since the last exacerbation	4.49 (3.91%)
Present symptoms	
Fatigue	28 (93.30%)
Numbing	21 (70.00%)

Pain	17 (56.70%)
Problems with sight	22 (73.30%)
Muscle spasm	23 (76.70%)
Bladder control disorders	26 (86.70%)
Bowel control disorders	15 (50.00%)
Sexual dysfunction	6 (20.00%)
Depression	13 (43.30%)
Cognitive difficulties	17 (56.70%)
Balance problems	26 (86.70%)
Poor coordination	26 (76.70%)
Walking disorders	28 (93.30%)
Tremor	16 (53.30%)
Speech difficulties	13 (43.30%)
Dizziness	16 (53.30%)
Disturbed heat sensitivity	19 (63.30%)
Presence of other diseases	
Not	24 (80.00%)
Osteoporosis	1 (3.30%)
The stomach ulcer	2 (6.70%)
Osteoporosis	2 (6.70%)
Diabetes	1 (3.30%)
Rickets	1 (3.30%)
Working status prior to MS	
Unemployed	1 (3.30%)
Employed	28 (93.40%)
Retired	1 (3.30%)

Z-scores were calculated on all scales of Waterloo-Battery for apraxia assessment for each participant suffering from MS separately. These results are shown in Table 2, of all the above-mentioned scale for creating achievement patterns, only z-scores are used on recognition, pantomimes delayed imitation of the movements and concurrent imitation of the movement scales. If the deviation in the achievements from the control group would be greater than -2 SD (for example, -3, -4), for the achievement in that task, with the abbreviation that signifies the task, the minus (-) would be marked in the table, while for minor deviations, after the abbreviations of the task, a plus (+) would be marked in the table. In this way, each participant would receive his own achievement pattern, which is also shown in Table 2.

In addition to the achievement pattern, the order number of the pattern, according to Roy's model, was marked. A pattern of achievement, indicating that achievements on all tasks were preserved, was marked with 0. It was found that, in addition to the 8 patterns defined by Roy as part of the model in the case of persons suffering from MS, 4 additional patterns were reported (Pattern 9: P+DI+CI-ID-; Pattern 10: P+DI+CI-ID+; Pattern 11: P+DI-CI+ID-; Pattern 12: P+DI+CI+ID-).

Table 2 Achievements and patterns of achievement on scales of adapted Waterloo-Sunnybrook apraxia battery

No.	Pattern no.	Pattern	Naming		Identification		Recognition		Pantomime		Delayed Imitation		Concurrent Imitation		Tool Use	
			z - score	Performance	z - score	Performance	z - score	Performance	z - score	Performance	z - score	Performance	z - score	Performance	z - score	Performance
1	0	P+DI+CI+ID+	0.59	+	0.41	+	-0.02	+	0.99	+	0.32	+	0.74	+	0.49	+
2	8	P-DI-CI-ID-	-3.85	-	0.41	+	-2.6	-	-5.22	-	-36.81	-	-75.39	-	-29.91	-
3	/	/	-3.85	-	-2.43	-	-4.03	-	-7.05	-	-32.88	-	-65.84	-	/	/
4	8	P-DI-CI-ID-	-1.63	+	-6.54	-	-13.2	-	-5.77	-	-38.56	-	-57.58	-	-11.16	+
5	9	P+DI+CI-ID-	0.59	+	0.41	+	0.62	+	-1.57	+	-1.87	+	-2.36	-	-3.06	+
6	0	P+DI+CI+ID+	0.59	+	0.41	+	0.62	+	0.99	+	0.75	+	0.74	+	-0.52	+
7	1	P+DI-CI-ID-	0.59	+	-1.17	+	0.62	+	-7.05	-	-26.04	-	-65.07	-	-22.31	-
8	8	P-DI-CI-ID-	0.59	+	0.09	+	-7.77	-	-7.6	-	-38.56	-	-78.23	-	-15.22	-
9	4	P+DI-CI+ID+	-3.85	-	-0.54	+	0.62	+	-1.39	+	-3.03	-	-1.58	+	-0.52	+
10	10	P+DI+CI-ID+	0.59	+	0.41	+	-0.02	+	-0.47	+	-0.12	+	-2.87	-	-1.54	+
11	0	P+DI+CI+ID+	0.59	+	0.41	+	0.62	+	0.44	+	0.32	+	-1.32	+	-0.52	+

12	0	P+DI+CI+ID+	0.59	+	0.41	+	0.62	+	0.08	+	-1.43	+	-1.32	+	0.49	+
13	10	P+DI+CI-ID+	0.59	+	0.41	+	0.62	+	0.99	+	-1.29	+	-5.71	-	0.49	+
14	7	P-DI-CI-ID+	-1.63	+	-0.22	+	-0.67	+	-2.48	-	-7.69	-	-10.36	-	-5.59	-
15	6	P+DI-CI-ID+	0.59	+	0.09	+	-0.67	+	-0.84	+	-3.62	-	-7.26	-	-1.03	+
16	0	P+DI+CI+ID+	0.59	+	0.41	+	0.62	+	-1.75	+	0.75	+	0.74	+	0.49	+
17	/	/	/	/	/	/	/	/	-2.66	-	/	/	/	/	/	/
18	10	P+DI+CI-ID+	0.59	+	-1.49	+	-0.67	+	-0.11	+	-0.56	+	-2.1	-	-2.55	-
19	11	P+DI-CI+ID-	-1.63	+	-0.22	+	-4.54	-	0.08	+	-2.16	-	0.74	+	0.49	+
20	0	P+DI+CI+ID+	0.59	+	-0.85	+	0.62	+	-1.93	+	-0.12	+	0.74	+	-6.1	-
21	1	P+DI-CI-ID-	0.59	+	0.09	+	-3.25	-	0.08	+	-4.93	-	-10.87	-	0.49	+
22	10	P+DI+CI-ID+	0.59	+	0.41	+	-1.31	+	0.44	+	0.75	+	-2.87	-	-0.52	+
23	0	P+DI+CI+ID+	0.59	+	0.41	+	0.62	+	0.62	+	0.75	+	0.74	+	-0.52	+
24	0	P+DI+CI+ID+	0.59	+	-1.17	+	-1.31	+	0.44	+	-0.41	+	-1.32	+	-0.52	+
25	10	P+DI+CI-ID+	0.59	+	0.41	+	0.62	+	0.99	+	0.02	+	-2.1	-	0.49	+
26	12	P+DI+CI+ID-	-1.63	+	-3.38	-	-2.86	-	0.62	+	-0.12	+	-1.32	+	0.49	+
27	0	P+DI+CI+ID+	-3.85	-	0.41	+	0.62	+	0.99	+	0.75	+	0.74	+	-0.52	+
28	1	P+DI-CI-ID-	-1.63	+	-2.75	-	-9.19	-	-1.57	+	-19.48	-	-11.39	-	-3.06	-
29	7	P-DI-CI-ID+	-1.63	+	-0.85	+	0.62	+	-2.3	-	-4.63	-	-12.42	-	-6.1	-
30	12	P+DI+CI+ID-	-1.63	+	0.41	+	-2.6	-	-1.93	+	0.75	+	-0.03	+	0.49	+
P=Pantomime; DI=Delayed Imitation; CI=Concurrent Imitation; ID=Gesture Identification; (+) denotes normal performance; (-) denotes impaired performance																

Table 3 shows the distribution of participants suffering from MS in relation to which achievement pattern is present in a person. Thus, it was found that in as many as 32.14% of the participant's achievements do not deviate much from the achievements of the control group on all tasks. Other participants have a deviation of more than 2 SD at least on one of the tasks. Out of the total number of participants that suffer from MS, in 17.86% of the participants, the pattern 10 is present. This pattern is present in the largest number of participants in which there are deviations from the control group in the achievements on the tasks. About 10.71% of participants have pattern 1 and pattern 8 present.

Table 3 Distribution of participants in relation to the present achievement pattern

Apraxia Performance Pattern	System Affected	N	%
Patterns within the conceptual-production system of the voluntary motor action by Erik Roy			
P+DI+CI+ID+	0-Not Affected	9	32.14%
P+DI-CI-ID-	1-Sensory/Perceptual	3	10.71%
P-DI+CI+ID-	2-Conceptual	0	0.00%
P-DI+CI+ID+	3-Production	0	0.00%
P+DI-CI+ID+	4-Production	1	3.57%
P-DI-CI+ID+	5-Production	0	0.00%
P+DI-CI-ID+	6-Production	1	3.57%
P-DI-CI-ID+	7-Production	2	7.14%
P-DI-CI-ID-	8-Conceptual and Production	3	10.71%
Additional patterns that are not defined within the conceptual-production system of voluntary motor action by Eric Roy			
P+DI+CI-ID-	9-Additional Pattern	1	3.57%
P+DI+CI-ID+	10-Additional Pattern	5	17.86%
P+DI-CI+ID-	11-Additional Pattern	1	3.57%
P+DI+CI+ID-	12-Additional Pattern	2	7.14%
Total		28	100.00%
P=Pantomime; DI=Delayed Imitation; CI=Concurrent Imitation; ID=Gesture Identification; (+) denotes normal performance; (-) denotes impaired performance			

DISCUSSION

Not only the expectations that the dominant achievement pattern for people suffering from MS is pattern number 7 were not fulfilled, but it has also been established that, with this group of participants, additional forms, that are not defined within the framework of Roy's model conceptual-production system of voluntary motor action, appeared. In 32.14% of participants, there were no major deviations in achievements on all scales of adapted Waterloo-Sunnybrook apraxia battery. The dominant form of achievement was the 10th pattern, which is not defined in the model. Before

analyzing the distribution of participants in relation to additional forms, we will analyze the distribution of participants according to those achievement patterns defined in the framework of Roy's model of the conceptual-production system of voluntary motor action.

With the largest number of participants, the 1st, 8th, and 7th forms are present. With a total of 28.53% of participants suffering from MS, one of these 3 patterns of achievement is present. The majority of participants have problems at the level of the sensory/perceptive system. They are not able to adequately recognize gestures and gestural errors, which is why the quality of both concurrent and delayed imitations of the movement is reduced, while the execution of the pantomime is preserved, because it does not require recognition of gestures and gestural errors for its performance, but rather relies on knowledge of mechanical characteristics of tools and gestures. This knowledge was created much before the onset of the disease, which is why it was preserved in these participants. The same number of participants has impairment at the level of the conceptual and production system. Although our forecasts were not correct, the pattern 7 is present in 2 participants. These participants have difficulty in organizing responses and motor control. Also, pattern 6 is present in 1 participant. He is able to analyze visual gesture information, however, the quality of pantomime is not satisfactory because he is not able to use preserved information with the goal of organizing and controlling the movement. One person had an impairment in working memory, which was shown in pattern 5. This person has impaired delayed imitation of the movement as a result of the impossibility of encoding visual gesture information into the working memory.

As for the additional forms that are not defined by Roy's model, it must be emphasized that the obtained results within this doctoral dissertation are not the first to point out the existence of additional achievement patterns [5]. Namely, Stamenova found additional achievement patterns in people with corticobasal syndrome [11]. In these participants, there are patterns: P+DI+CI-ID+, P-DI+CI-ID+, and P+DI+CI+ID-. Stamenova thinks that the P+DI+CI-ID+ pattern represents impairment at the level of the production system [11]. In this case, attention control is damaged. This pattern is very important when it comes to the results of our research. Namely, with most people with MS (17.86%), exactly this pattern is present. As part of our research, it is marked as pattern 10.

Stamenova's second additional pattern from her research, P-DI+CI-ID+, marks a pattern that occurs when a selection of response and/or generation of performance is damaged, and when there are problems of attention control [11]. This pattern is not very important for our study because it was not present in any participant. However, the following pattern (P+DI+CI+ID-, denoted as pattern 12 in our research), is the one which Stamenova described as impairment of the input of the conceptual system [11].

Roy did not predict that a case, where the pantomime and the delayed imitation will be preserved, while concurrent imitation will be damaged, which might occur [5]. He considered that it is necessary to encode the visual information in the working memory to perform the delayed imitation, while this is not necessary for performing concurrent imitation. However, it has been shown that the majority of people suffering from MS have an exact additional pattern 10, where only concurrent imitation is damaged. Stamenova considers that concurrent imitation is much more lenient than the working memory, because the person at the same time perceives and processes information, but also performs the movement [11]. Therefore, she states that concurrent imitation is actually a dual task and considers that this pattern of achievement disturbs the control of attention. We believe that people with MS could have poor achievements because of demyelination. It is possible that the flow of information is slower and only those systems that are sufficient to partially process the information are activated, which is why the feedback of the perception and action relation is endangered. This could be an additional explanation for the aforementioned pattern. Many studies have shown that people with multiple sclerosis have difficulties in performing dual tasks [12,13].

In Roy's model, there are no patterns within which the recognition is impaired, but tasks of performing the movement are preserved. Roy states that the inability to recognize gestures is a consequence of an inability to process visual information or of loss of conceptual knowledge [5]. If there is a deficit at the level of processing of visual information, the person will not be able to imitate the movement well. If there is a deficit at the level of the conceptual system, a person will not be able to perform a high-quality pantomime. In our research, one person was found to have a pattern 12, in which the recognition was damaged, and the tasks of carrying out the movement were preserved. Rothi, et al., described people who had similar achievements as a participant in our study [14]. The people were not able to recognize the gestures, but they could carry out the pantomime and imitation of the movement. They named these

achievements "pantomime agnosia". According to these authors, in people with pantomime agnosia, the connection between the visual input and the so-called "input praxicon" is interrupted. Unlike Roy's model, Rothi and Heilman's model of apraxia implies the existence of 2 independent sets of conceptual representations, one for the processing of gestural input information (input praxicon) and the other for processing a gestural output (output praxicon). For this reason, if the representations, which are responsible for processing incoming visual-gestural information, are impaired, the person will not be able to visually recognize the gesture but will be able to perform pantomime and imitation [15].

According to what has been said so far, a person with MS with pattern 11 present has a working memory damage and is unable to retain generated presentations necessary for the performance of the pantomime, nor is able to encode the visual information about the gesture in the working memory, and at the same time, there is a dysfunction in processing input information into the conceptual system (same as the additional pattern 12).

There is a pattern 9 in 1 participant suffering from MS. This pattern is characterized by the fact that recognition is limited, the pantomime and the delayed imitation are preserved, while the concurrent imitation is impaired. With this pattern, it is most likely for impairment to be present at the level of dual-task processing and attention control, as in pattern 10, and at the same time, there is damage to the conceptual system input, as in pattern 12.

CONCLUSION

The assumption that the dominant pattern of achievement of participants suffering from multiple sclerosis indicates a damaged response organization and control (pattern 7) was not confirmed, although 2 participants of this research had this pattern present.

Dominant achievement pattern in people suffering from MS is additional pattern 10 (P+DI+CI-ID+), which indicates impairment at the level of the production system, and especially problems of dual processing of information and slow processing, as well as difficulties in attention control. The following patterns, in relation to a number of participants they were present in, are patterns 2 and 8. The first refers to the impairment at the level of the sensory/perceptive system, and the second denotes impairment to both conceptual and production systems. It should be noted in particular that the largest number of participants did not have large deviations from the control group on a single scale of adapted Waterloo-Sunnybrook apraxia battery.

Results show that Roy's model of the conceptual-production system of voluntary motor action is applicable to the population of MS patients, but with the acceptance of the existence of additional forms of achievement that Roy did not define. It is recommended that within the framework of future research the ability of the model to predict the presence of disability should be investigated.

DECLARATIONS

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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