Research Article

The Relationship between Cognitive Function, Syntax, and Severity of Dysarthria in Persian Patients with Multiple Sclerosis

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Abstract

Introduction: Multiple Sclerosis (MS) is a degenerative disease affecting the central nervous system. Patients with MS experience difficulties in speech, language, and cognitive abilities. This research aimed to explore the relationship between cognitive functions, syntax, and the severity of dysarthria in Persian patients with Relapsing-Remitting Multiple Sclerosis (RRMS), compared to healthy individuals.

Mterials and Methods: In this cross-sectional study, 31 patients diagnosed with RRMS were compared to 31 healthy adults matched by age, gender, and education. Participants were assessed using the Montreal Cognitive Assessment, the syntax comprehension sub-test from the Bilingual Aphasia Test, and the sentence production test. Dysarthria was evaluated through the Frenchay Dysarthria Assessment (FDA-2a), and severity was determined using the visual analog scale by three speech and language pathologists based on recorded speech samples.

Results: Findings showed significant differences between MS patients and the control group (P≤0.05). Dysarthria severity correlated significantly with syntax comprehension (P=0.002, Cohen's d=0.803), syntax production (P=0.005, Cohen's d=0.820), and MoCA (P=0.001, Cohen's d=0.579). Significant correlations were also found between MoCA and syntax comprehension and production within the patient group (P≤0.05). Data were analyzed using SPSS version 26. Differences between groups were calculated by an independent t-test, and correlations were analyzed with the Spearman test at a significance level of P≤0.05.
Conclusion: Syntactic challenges in MS patients may be linked to cognitive impairments, and as dysarthria severity increases, syntactic problems escalate. These results can assist speech and language pathologists in clinical evaluations and comprehensive interventions.
Keywords: Multiple Sclerosis; Cognition; Syntax; Dysarthria; Persian language.

1.Introduction

Multiple Sclerosis (MS) is a degenerative disease affecting the central nervous system, characterized by the damage of the myelin sheath around nerve cells and the formation of plaques in the brain and spinal cord's white matter [1]. The prevalence of MS in the world has been reported as 35.9 people per 100000, while research has estimated a range from 5.3 to 74.28 individuals per 100000 in Iran, suggesting a rising trend in the incidence of this condition in the country [2, 3]. The prevalence of this disease in females was four times that males, and currently, and it is currently recognized as the second leading cause of disability among Iranian youth [4]. According to the speed of disease progression and MRI results, there are four clinical types of MS: Clinically isolated syndrome (CIS), Relapsing-Remitting MS (RRMS), Secondary- Progressive MS (SPMS), and Primary Progressive MS (PPMS). The most common type of disease is RRMS, which affects 85 to 90% of patients [5,6]. This type of disease is characterized by unpredictable attacks or relapses followed by either partial or complete recovery. Relapses typically happen in a sub-acute manner, arising within several hours to a few days; symptoms then stabilize for several weeks before gradually improving during the recovery phase, which can extend over weeks to months.

Individuals diagnosed with progressive neurological diseases such as MS experience a wide range of challenges, with symptoms that extend beyond sensory and motor dysfunction. Historically, it was believed that the damage caused by this disease primarily affected subcortical brain regions, while cortical regions were considered primarily responsible for language processing. As a result, the interaction between cognitive and linguistic functions in this population remained largely unexplored in earlier research [7]. Approximately 75% of individuals with MS self-reported experiencing language difficulties, including naming [8], high-level pragmatic skills [9,10], semantic paraphasia [11] and problems in syntax characterized by a reduction in word count, omission of grammatical elements, and shorter mean utterance lengths [12,13,14]. Furthermore, these individuals demonstrate lower linguistic complexity [11] and struggle with the comprehension high-level language, such as metaphors and idioms [15]. The prevalence of cognitive impairments in MS patients ranges from 40% to 65% [16,17]. MS affects various aspects of cognitive performance, leading to difficulties in attention, both short and long-term memory, speed processing, information processing and executive function. Additionally, these patients experience challenges in visual-spatial and verbal learning, and their ability to recall information is often delayed [1, 18]. Dysarthria as a speech disorder has a prevalence of 40 to 55% in MS patients, which statistics indicate the symptoms of dysarthria in MS patients- including slurred speech, production problems, slow speech rate, and drooling- should be closely monitored [19]. According to King (2009), there is a significant relationship between the severity of dysarthria

(assessed through intelligibility) and cognitive-linguistic deficits; furthermore, if individuals with MS do not exhibit cognitive deficits, the syntax and length of their sentences remain typical and show no significant difference compared to non-patients [20].In the same direction, Rahimifar et al.,(2017) investigated the effect of cognitive impairments through the repetition of long sentences in Persian, revealing a correlation between cognition and syntax; patients without cognitive deficits did not experience any syntactic problems [12]. On the other hand, a relationship has been shown between cognitive problems and the severity of patients' dysarthria [21]. As previously noted, MS impacts both sensory and motor functions, involving cortical and subcortical regions of the brain. Consequently, patients with MS often exhibit varying degrees of impairment in speech and language, cognitive abilities, and motor skills. This raises the question of whether a significant association exists between cognitive functioning, language deficits, and the severity of dysarthria in this population.

In general, the findings of the studies suggest the potential for cognitive and language difficulties across different types of MS, without attributing these difficulties to a particular type of the disease [22,23,24]. Additionally, research indicates that patients with dysarthria tend to perform worse on cognitive and language tests, it is reasonable to hypothesize that greater severity of dysarthria is associated with a marked decline in cognitive and linguistic test performance [19,21,22]. Given that language assessments were confined to specific aspects of language, such as naming and cognitive assessments were also restricted to certain tests for these patients [13,17], it appears crucial to conduct a more thorough and in-depth analysis of language disorders such as syntax—which encompasses comprehension and production—and to explore cognitive abilities and the severity of dysarthria in patients with MS. The hypothesis of the present study is that there is a relationship between cognitive impairment, syntax, and severity of dysarthria in patients with MS. Therefore, the study aimed to determine how syntax, cognition, and the severity of dysarthria connect with these patients. Also, it was assessing the performance of patients with MS in the syntax comprehension and production as well as cognitive abilities, comparing these results with those from matched healthy non-patients. With these results, speech and language pathologists will be able to enhance their evaluation and treatment services for these patients, the final result of which will lead to the improvement of the quality of life, reduction of treatment costs and acceleration of the treatment process.

2. Method

2.1. Participants

In this cross-sectional research, the study investigated whether the syntactic and cognitive skills of patients with RRMS differ from those of healthy individuals, and whether there is a relationship between syntax, cognitive skills and the severity of dysarthria in these patients. The sample for this research consisted of 31 patients with RRMS from the Iranian MS Association and 31 matched healthy individuals in terms of age, sex, and education. Healthy participants were recruited from public locations such as libraries, sports centers, and other community settings to ensure accessibility and population diversity.

Sampling was conducted after receiving the ethics code from the Tehran University of Medical Sciences ethics committee (IR.TUMS.FNM.REC.1402.069). Before the sampling process, the informed consent form was completed by the patient or their family members.

The subjects of this study met the following criteria for inclusion: a) the age range was between 18 to 65 years, b) being monolingual in Persian (in case of bilingualism, they demonstrated full proficiency in the Persian language), c) having at least elementary literacy, d) not having vision

and hearing problems or uncorrected hearing and vision, e) were diagnosed with RRMS and not used steroids in the preceding 8 weeks, f) their disease duration was at least 2 years, g) exhibiting dysarthria according to the second version of the French dysarthria assessment (FDA-2) [25], and h) not have any other neurological and psychological problems as determined by a neurologist and psychiatrist. Once the patients meeting the inclusion criteria were included in the study, the research team conducted the FDA-2 test to identify patients with dysarthria; those without dysarthria and individuals unwilling to participate were removed from the study. The criteria for including healthy non-patient participants were the same, with the exception of having MS. Participation in the sampling was voluntary, and the participants were guaranteed that their information would be remaining confidential.

2.2. Assessment tools

The assessment tools used in this research comprised the following:

2.2.1. The personal information questionnaire: aimed at gathering information such as age, gender, educational background, duration of the disorder, co-morbidity and medications.

2.2.2. The French Dysarthria Assessment test-2 (FDA-2) (Persian version): to detect the presence of dysarthria in patients with MS. This test consists of various parts to evaluate reflexes, breathing, lips, tongue, larynx and intelligibility. Each part is assigned a qualitative score, and ultimately, the overall performance is determined if the individual has dysarthria. The test demonstrates strong validity and reliability, with content validity at 95% and internal consistency measured at 0.96 ($P \leq 0.5$) [25].

2.2.3. The Persian adaptation of the Montreal of Cognitive Assessment (MoCA-P): to determine individuals' cognitive performance. This test measures cognitive performance through various domains, including short-term memory, visual-spatial skills, executive functions, attention, concentration, working memory, language, and time and place orientation. A score below 26 indicates that the individual may have cognitive impairments. The MoCA exhibited good sensitivity in identifying MCI and AD (90% and 100%, respectively) [26].

2.2.4. Sentence production test: in this test, individuals' syntactic skills are examined through their ability to create sentences using 20 reversible transitive Persian verbs across four sentence types (active, passive, tropicalized, and focusing). The participant is allotted 10 seconds to produce a sentence according to the provided pictures. A total of 80 sentences are presented, with 1 score is given for each correct answer; however, if any word are missing or if the verbs are incorrectly chosen, the answer is considered as incorrect and receives a score of 0. For this test, the content validity for verbs ranged from 63.87 to 94, while the content validity of nouns was between 82.33 and 94. Each verb was paired with four types of sentences, and the face validity of the pictures representing these sentences was assessed to be between 85 and 96.67 [27].

2.2.5. Syntax Comprehension subtest of Bilingual Aphasia Test (BAT-Farsi version): to determine individuals' performance in syntax comprehension. In this test, the examiner reads a total of 86 sentences, which include active, passive, subject relative clauses, and object relative clauses, and the participant must select and indicate the correct picture that corresponds to each sentence. Each correct answer is awarded 1 point; conversely, if the participant answers incorrectly or fails to respond within the allotted time, they receive a score of zero. The scoring range for this subtest is from 0 to 86, with higher scores reflecting better comprehension skills [28].

2.2.6. In order to evaluate the severity of dysarthria, speech samples from patients, which included descriptions of a “bird's nest” picture and their job, were recorded and analyzed by three speech and language pathologists who specialize in speech motor disorders. Each evaluator assigned

scores according to the intelligibility and speed of conversation, while also taking into account the frequency and length of pauses, using a visual analog scale (VAS) that ranged from 1 to 10, where a higher score indicated a greater severity of dysarthria. By averaging the scores from three evaluators, the severity of dysarthria was established for each individual.
Finally, the data was analyzed by SPSS software version 26. In the descriptive statistics, we calculated the mean, standard deviation and mean difference for cognitive, syntax and severity of dysarthria. The independent t-test was utilized to assess the differences between the two patient groups and healthy non-patients, and the correlation between them was evaluated with the Spearman test at a significance level of $P \leq 0.05$.

3. Results

In this research, 62 individuals participated in two groups of patients with MS and one group of healthy non-patients who were homogeneous in terms of age, gender and education with the patients. Among the participants, 80 percent of patients and 71 percent of healthy individuals were female, resulting in a ratio where the number of female patients was four times that of male patients. There was no significant difference between the two groups regarding age, gender and educational level ($P>0.05$). Table 1 presents a comparison of average scores for syntax comprehension, syntax production, and cognitive abilities as assessed by the MoCA, highlighting a significant difference ($P < 0.05$).

Table 1. Comparison of mean scores of syntax comprehension, syntax production and cognition between two groups (n=62)

Test Type	Participant Group	Mean	Std. Deviation	Confidence Interval (Lower)	Confidence Interval (Upper)	Degrees of Freedom	t-value	P-value	Cohen's d
Syntax Comprehension	**Patients (n=31)**	78.39	9.46	-9.21	-2.009	35.39	-3.16	0.003*	0.803
	Non-Patients (n=31)	84	2.85						
Syntax production	**Patients (n=31)**	71.32	10.59	-10.30	-2.33	33.67	-3.22	0.003*	0.820
	Non-Patients (n=31)	77.65	2.62						
Cognition	**Patients (n=31)**	25.35	3.62	-3.28	-0.20	60	-2.26	0.027*	0.579
	Non-Patients (n=31)	27.1	2.27						

Cohen`s d interpretation=0.2-0.49=small. 0.5-0.79=medium, ≥0.80=large

It should be noted that the average duration of disease in the patients was 11.42 ±7.27 years, while the average severity of dysarthria was recorded at 2.72± 1.56. In Table 2, Spearman's correlation coefficient has been utilized to explore the relationship between disease duration and dysarthria severity in relation to the scores for syntax comprehension, syntax production, and cognitive function.

Table2. The correlation coefficient of the dysarthria severity with the scores of syntax comprehension, syntax production and cognition.

		Syntax comprehension	**Syntax production**	**Cognition**	**Severity of dysarthria**
Severity of dysarthria	**Correlation coefficient**	-0.53	-0.48	-0.58	1
	P-value	0.002*	0.005*	0.001*	-

The results indicate a negative and significant correlation between the severity of dysarthria and both syntax comprehension, syntax production, as well as cognition ($P < 0.05$). In other words, as the severity of dysarthria increases, scores for cognition, syntax comprehension, and production tend to decrease. Table 3 illustrates the relationship between syntax comprehension, syntax production and cognition in the patients, indicating this correlation is both significant and strong ($P<0.05$).

Table 3. Correlation between syntax comprehension, syntax production and cognition in patients (n=31)

	Syntax comprehension		**Syntax production**	
	r	**P**	**r**	**P**
Syntax comprehension	1	-	0.65	0.000*
Syntax production	0.65	0.000*	1	-
Cognition	0.75	0.000*	0.79	0.000*

4. Discussion

The current study was carried out to compare cognitive performance, syntax comprehension and syntax production in MS patients and healthy non-patient individuals. Additionally, it explored the relationship between cognition, syntax comprehension and production in MS patients, along with the severity of dysarthria which is discussed separately below.

The findings showed that although multiple sclerosis is four times more common in women than in men, there is no significant difference between syntax and cognitive function or the severity of dysarthria between the two genders.

This section outlines the objectives of the study, which are addressed in two subsequent parts: first, the comparison of syntactic comprehension and production, as well as cognitive performance, between individuals with MS and healthy controls; and second, the examination of the study's hypothesis concerning the relationship between dysarthria severity and syntactic and cognitive functioning in patients with MS.

4.1. The comparison of syntax comprehension and production with cognition in MS patients and non-patients

The findings of the present study indicated that there are significant differences in syntax comprehension and production, as well as cognition in Persian-speaking individuals with Relapsing-Remitting MS compared to healthy non-patients with patients scoring lower. This finding is consistent with Jamalpour et al. (2014), Rahimifar et al. (2017) and Zivadinov et al. (2001) [12,29,30], all of which demonstrated that syntactic functions are diminished in patients relative to healthy non-patients. In Jamalpour et al.'s study, the patients exhibited no cognitive problems; however, through descriptive task and spontaneous conversation, they concluded a significant difference between the mean length of the longest utterances and the total number of sentences between MS patients and healthy individuals, indicating that MS patients experience difficulties in syntax production. Using the repeating long sentences task, Rahimifar et al. (2017) [12 found that individuals with MS who do not exhibit cognitive impairment had a greater tendency to omit content words and reduce their overall word count compared to healthy individuals. Similarly, Zivadinov et al. (2001) [30] also evaluated Relapsing-Remitting MS patients who did not have cognitive deficits by using the BAT test. The findings from these studies suggest that even patients without cognitive challenges demonstrate poorer syntactic abilities compared to their healthy counterparts. The study by Subert et al. (2023) [14] considered the reduction of sentence length and the decreased use of grammatical words in both conversations and spontaneous speech as a syntactic characteristic among individuals with MS, which aligns with earlier studies. Additionally, the work of Soltani & Rahimifar (2020) [13] analyzed tasks such as picture description, sentence repeating and spontaneous speech, revealing that the syntactic difficulties faced by patients are particularly associated with those having cognitive impairments.

Although the studies involving Persian speakers have used various tasks and different sample sizes, they all studies consistently reveal that patients with this type of MS experience syntactic difficulties, regardless of cognitive impairments present in the subjects or the specific tasks employed for syntax comprehension and sentence production. In essence, the goal of the aforementioned studies is to compare the syntactic difficulties faced by patients with those of healthy individuals, while controlling for cognitive effects.

In more detail, the findings of the present study indicate that in patients with MS, there is a significant correlation between syntax production and the cognitive performance, as well as between syntax comprehension and cognitive abilities. Consequently, individuals who perform better on cognitive assessments tend to achieve higher scores in both syntax comprehension and production. This finding is in line with the results of Grigoriadis et al. (2024) [18] and Sonkaya & Bayazit (2018) [31], who stated that patients experiencing cognitive difficulties often display decreased syntactic performance, with this decline worsening as cognitive difficulties intensify.

Also, Arronda et al. (2010) [15] found a significant correlation between cognitive performance in patients and the length of their sentences, revealing that individuals with cognitive impairments tend to produce shorter sentences and fewer words compared to their peers who do not have cognitive difficulties and healthy non-patients individuals. Therefore, the findings from various studies, regardless of the use of different syntactic and cognitive tests, indicate presence of issues concerning syntactic comprehension and production. Furthermore, these syntactic problems are positively correlated with cognitive difficulty. In other words, as the cognitive impairments of patients increase, they exhibit greater deficits in both syntactic comprehension and production.

Additionally, the findings of this study showed that in patients, the correlation between syntax production and cognition was stronger than that between syntax comprehension and cognition.
It is important to point out that this study found a significant correlation between syntax comprehension and syntax production in patients with MS.
As a result, higher syntax comprehension was associated with improved syntax production. The research is among the initial studies examining syntax production with a reliable syntax assessment, attempting to explore syntax comprehension and production separately in these patients. Therefore, there was no other research under these specific conditions to establish this connection. Nevertheless, this study successfully validated the presence of deficits in both syntactic comprehension and production among MS patients.

4.2. The relationship between the severity of dysarthria and the syntax comprehension and production and cognition in MS patients.

The results also indicated a significant inverse correlation between the severity of dysarthria and syntax comprehension, syntax production, and cognitive functions, suggesting that as dysarthria severity rises, individuals' performance on these assessments declines. Mackenzie & Green (2009) [32], after examining the severity of dysarthria of patients based on their speech intelligibility reported a strong correlation between the severity of dysarthria and their outcomes on language tests, aligning their findings with those of our study. The findings from the review study conducted by Noffs et al. (2018) [33] and Feenaughty et al. (2021) [21] support the notion of a connection between dysarthria and cognitive impairments. However, Feenaughty et al., (2018) [22], upon examining the severity of dysarthria through speech intelligibility, showed that there is no significant relationship between speech intelligibility and cognitive performance. This discrepancy may arise from various factors, including difference in patient populations, the specific type of MS being studied, and the tests used to assess the severity of dysarthria and speech intelligibility.
Conversely, Mackenzie & Green (2009) [32], in their study of patients with chronic progressive MS, found a strong correlation between the severity of dysarthria (measured by speech intelligibility) and cognitive test performance, indicating that individuals with low speech intelligibility perform poorly in cognitive tests. Similarly, Smith & Arnett (2007) [19] after analyzing 97 patients with MS noted that the lower mean scores of patients in some cognitive tests were attributed to a reliance on verbal skills, but overall, those with dysarthria scored significantly lower on cognitive tests compared to their counterparts without dysarthria, and there was a significant negative correlation between the severity of dysarthria and cognitive test performance. Nonetheless, the decline in cognitive function of patients without dysarthria was also significant compared to their healthy non-patients. Overall, the results of our study revealed a negative correlation between dysarthria severity and both cognitive and syntactic abilities, indicating that increased severity of dysarthria was associated with lower performance in cognitive tasks as well as in syntactic comprehension and production. A negative correlation reflects an inverse association between speech motor abilities and linguistic and cognitive functions, whereby increased impairment in motor speech skills corresponds with diminished performance in language and cognitive domains.
The study's limitations included the inability to examine additional demographic characteristics in the patient group, such as motor disorder examination, disease severity-based division (e.g., EDSS scores), gender balance, the use of a larger sample size, and assess patients without dysarthria recruitment homogeneous control group. Therefore, it is suggested that in the future research look at psychological and social status in addition to physical and movement characteristics and

assessed how these factors affect the patients' cognitive abilities, speech, and language (e.g., spontaneous speech and functional language use). Additionally, it is recommended that various tests be used for these assessments in order to better and more precisely identify higher-level syntactic processing (e.g., ambiguity resolution), other cognitive tests, control the confounder variables such as fatigue, depression/anxiety, medications, and to evaluate suitable rehabilitation programs before the disease worsens.

4-3 Future Studies

Future research is anticipated to explore additional complex language functions in this patient population, as well as to investigate the associations between cognitive, linguistic, and speech impairments and relevant demographic variables.

5. Conclusion

In contrast to previous research, the present study examined the integrated relationship between dysarthria severity, cognition and syntax abilities, yielding novel insights into this domain this field. The findings indicate that individuals with MS exhibit significant impairments in both cognitive and syntactic domains compared to healthy controls. Specifically, patients with relapsing-remitting MS (RRMS) demonstrated markedly lower performance, highlighting difficulties in cognitive processing and syntactic comprehension and production. Moreover, cognitive deficits were closely associated with syntactic impairments, and both were exacerbated by increasing dysarthria severity. Although cognitive challenges were evident across all levels of dysarthria, greater severity intensified these difficulties. These results underscore the importance of comprehensive assessment by speech and language pathologists, including evaluation of syntactic and cognitive functions in individuals with MS.

Ethical Considerations

Compliance with ethical guidelines

The Ethics Committee of Tehran University of Medical Sciences approved this study (Code: IR.TUMS.FNM.REC.1402.069).

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Authors's contributions

Conceptualization and study design: Mohsen Miarkiani, Azar Mehri; Data acquisition: Mohsen Miarkiani; Data analysis and interpretation: Azar Mehri and Shohre Jalaei; Statistical analysis: Shohre Jalaei and Mohsen Miarkiani; Initial draft preparation: Mohsen Miarkiani, Azar Mehri; Review, editing and final approval: Mohsen Miarkiani, Azar Mehri, and Shohre Jalaei.

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Conflict of interest

There is no conflict of interest.

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