Journal of Neurology & Experimental Neuroscience

https://doi.org/10.17756/jnen.2023-102

Research Article | Open Access

An Individualized Intervention, Based on the Feldenkrais Method, for Multiple Sclerosis Symptoms: The Neuroplasticity Scale Assessment

Triantafillia Reziti*

Feldenkrais Praxis Athens, Monis Petraki, Attica, Greece

***Correspondence to:**
Triantafillia Reziti
Feldenkrais Praxis Athens, Monis Petraki
Attica, Greece
Tel: +30-2104411820, +30-2130332468
E-mail: filio@feldenkraismethod.gr

Received: October 12, 2022
Accepted: February 24, 2023
Published: February 26, 2023

Citation: Reziti T. 2023. An Individualized Intervention, Based on the Feldenkrais Method, for Multiple Sclerosis Symptoms: The Neuroplasticity Scale Assessment. *J Neurol Exp Neurosci* 9(1): 7-17.

Published by United Scientific Group

Abstract

Objective: Although numerous multiple sclerosis (MS) patients display decreased motor performance and cognitive deficits, little is known about rehabilitative methods and assessment strategies that are based on the brain's ability to learn through motor-cognitive patterns. Commonly used methods, such as the Expanded Disability Status Scale (EDSS) and the Berg Balance Scale (BBS), can only unravel limited new information on individual motor-cognitive experiencing and the capacity to change this through brain learning. Therefore, we set out to design a new tool for the simultaneous assessment of multiple parameters in MS patients: the Neuroplasticity Scale (NS) – an inductive rehabilitation methodology, based on Feldenkrais Method (FM) movement protocols.

Methodology: In this proof-of-concept study we performed our procedure on a single subject, an MS patient with severe instability and spasticity, who was carefully selected. Our methodology included a baseline evaluation (Week 0), followed by six weeks of intervention (Intervention Weeks 1- 6). NS assessment was performed both before and after the intervention. All throughout the procedure, the subject carried out home training, which was guided by auditory cues for perception, movement patterns, spatial orientation, movement timing, changes of attention and daily life functionality, and was used to establish subsequent practice.

Results: Based on the subject's significant balance improvement and spasticity reduction, the NS appears to be useful, easy to use and effective; in addition, it improves functional organization in specific motor patterns through brain learning.

Conclusion: The NS enables both practitioners and patients to assess changes in sensory-motor and cognitive processes during action; it is useful for qualitatively evaluating multiple parameters that define the current clinical image of an MS patient. Therefore, upon further refinement and wider application to additional patients, it may be used for the establishment of structured rehabilitative interventions and home training repetitive programmes, as well as improved questionnaires, based on an individual's specific functional needs.

Keywords

Multiple sclerosis, Feldenkrais method, Motor-cognitive intervention, Neuroplasticity, Rehabilitation

Introduction

Multiple sclerosis (MS) is a neurodegenerative disease of the central nervous system (CNS); it is characterized by inflammation, demyelination, chronically progressive deterioration and damage of axonal conductance and viability [1], which result in decreased motor performance of varying severity, as well as impairment of attentional processing [2]. It is estimated that MS affects approximately two million people worldwide [3]. Fatigue [4], cognitive dysfunction [5], physical disability [6] – especially in terms of balance [7] and postural control [8] – have been reported as common limitations in MS patients.

The severity of MS is assessed though several clinical instruments, which have been designed and used as an end-point in clinical trials that evaluate therapeutic procedures [9]. Specific clinical tools, such as two widely and frequently used assessment scales – the Extended Disability Status Scale (EDSS) [10] and the Berg Balance Scale (BBS) [11] – allow clinicians to evaluate disability and measure the effectiveness of treatment.

The EDSS is one of the most frequently used clinician-applied assessment scales: It is based on a structured neurological examination that evaluates a patient's functional systems (FS), attributing an average score from 0 to 10 [12]. The EDSS specifically measures impairment in eight functional systems, namely the Pyramidal (P), Cerebellar (CII), Brainstem (Bs), Sensory (S), Bladder-Bowel (BB), Visual (V), Cerebral/Mental (Cb) and other (O) [13]. However, despite the fact that it is used to assess disease progression and severity, as well as the efficacy of treatment interventions [9, 14], it is characterized by limited reliability and poor sensitivity [13]. More specifically, although cognitive dysfunction affects >50% of MS patients and develops early during the course of the disease [15], its correlation with walking performance is not considered in the EDSS assessment. In addition, the EDSS does not explore specific mechanisms of effect, such as MS-related fatigue, or stress factors during motor performance [12]; furthermore, it does not evaluate processes that reflect the multidimensional embodied perspective, including motor-cognitive integration [16].

In case of the BBS, postural control abnormalities and gait activities in MS are usually evaluated in relation to psychometric parameters [11]. Hence, bodily factors (e.g., interoceptive sensibility [17]) or other forms of body signal processing and spatio-temporal parameters during gait performance [18, 19] – that is, aspects that determine an individual's functionality in different sets of conditions and sometimes lead to long-term, increasing disability– are not included.

MS is a disease of variable nature: It restricts a patient's motor performance to a degree that may differ from day to day; it is thus impossible to objectively determine his/her endurance, balance and attention processing overall [12]. Although scientifically well-established and clinically useful [13], scoring scales such as the above-mentioned largely ignore the individual's embodied daily experience, and a gap is created between any applied methodology and the expected result – especially when the aim is to employ somatic educational approaches in the context of rehabilitation [20, 21]. Therefore, a significant question is raised about whether or not they can truly evaluate a subject's action as a simulation of perception, at a physical level [22], and whether or not they actually allow clinicians and researchers to unravel new information regarding individual motor-cognitive experience, as well as the capacity to change this through brain learning.

These restrictions highlight the absolute necessity of redefining clinical approaches under the scope of a "body-in-the-brain" model. This model postulates that the body functions by responding to temporary coherent settings, depending on the information it perceives through constructed neural maps, in order to facilitate the development of personalized, moment-to-moment, adaptations to environmental cues, as well as its own biological regulation and the maintenance of vital processes [23].

Contrary to previous methodological intervention procedures, the Feldenkrais Method (FM) [24], a somatic educational approach [25], is based on the integrated process of the above model; it focuses on developmental changes through self-awareness and brain plasticity, and illuminates fundamental aspects of functionality [26]. One of the principles of the FM is that the processes of thinking, feeling and sensing are all interrelated components of human functioning, and that, as a consequence, the only way to address any of these components is to address them all [27]. Acknowledging that this interrelation is a key potentiality factor in MS rehabilitation, we are prompted to reconstruct our kinetic and kinematic strategies for movement, incorporating attentional properties.

The purpose of this study is to present, as a proof-of-concept, a new tool that we have devised, in order to enable both practitioners and MS patients to assess changes in sensory-motor and cognitive processes during action: the Neuroplasticity Scale (NS). The NS is an effective inductive methodology and evaluation approach, which bridges the gap between applied research metrics and somatic education methods, by simultaneously assessing multiple parameters that have not been previously captured in MS patients. Crucially, although some indicators and parameters used in the NS are also encountered in the FM, our methodology includes in addition: (i) indicators that are based on the individual's own remarks, in the form of pre- and post-intervention self-reports; (ii) a constraint report during action; (iii) NS evaluation; and (iv) home training.

Method

Recruitment of subject

To design and test our NS tool, we recruited a single subject, based on three selection criteria: (a) The subject had to display a clinical image that would allow full compliance with a six-week intervention programme, including home training; (b) the subject had to be willing to undergo evaluation; and (c) the subject had to present motor-cognitive deficits that could be investigated based on specific indicators. Hence, a 67-year-old female subject with a clinically defined diagnosis of MS was recruited through the practice of a local neurologist. Three weeks prior to the procedure in 2019, the subject was clearly informed about the scope and details of the research and provided full consent. The subject had been diagnosed with MS approximately thirty years prior to our procedure. In fact, the initial diagnosis was Lyme disease, with fatigue as the main neurological symptom, but subsequent clinical tests and magnetic resonance imaging (MRI) supported the diagnosis of MS. At the time of the study the patient presented secondary progressive MS (SPMS); she suffered from changes in cognitive performance, especially in her working memory

(WM) and attention (e.g., focused/selective attention and divided attention) [28, 29]. She also experienced fatigue, as well as severe lower limb spasticity and weakness, associated with walking dysfunction and instability, increased plantar flexion, inability to spread and lift the toes, moderate-to-significant right kyphoscoliosis that was worsening over time and causing her further difficulty in motion, as well as lower back pain. She used an assistance device (cane) for walking. In the past, due to her progressive instability, the neurologist had recommended rehabilitation, including ozone therapy, acupuncture, and several variations of classical physiotherapy, but none of these methods worked. As a result, the patient had expressed increasing concerns about disability, and her fatigue and impairment had led to several falls. She had had MRI scans of the brain and spinal cord in 2001 and 2011, which showed multiple demyelinating lesions in the periventricular white matter and across the length of the cervical spinal cord, none of which ever showed neither gadolinium enhancement nor significant change.

Design of the NS tool

Our purpose was to design an assessment tool that would allow us to contextualize and analyze the limitations of MS patients during the perception-action internal and external constructive process, in order to address complex clinical issues that disturb such patients. Based on the FM Method, we thus designed the NS assessment tool (Table 1). The NS involves three sections (Sections I, II, and III), during which the practitioner collects data on three specific motor-cognitive functional areas, in the form of specific indicators (e.g., spasticity, fatigue, spatial orientation, time and rhythm change perception, balance parameters, etc.). Section I involves an exploratory manipulation through touching (hands-on work), in the form of a functional integration (FI) process (for further explanation see [2] in Appendix A), according to specific MS symptomatology and kinesthetic awareness of the subject; this section is performed solely during intervention, by the practitioner, on the subject. Section II involves a modifiable training, which is based on awareness-through-movement (ATM), on published data and on a constraints' assessment by the practitioner through NS evaluation during execution. Section III involves assessment, both by the practitioner and the subject, of reference actions, namely standing, walking, and sitting. Sections II and III – that is, ATM sequences and reference actions – form the "home training", which the subject executes following recorded auditory cues. Importantly, Section III is, in part, based on the Short Physical Performance Battery protocol [30]. All indicators evaluated in each Section are explained in detail in Appendix A.

Procedure Overview

The procedure we performed on the selected subject included six weeks of intervention (Weeks 1 to 6), preceded by one week of baseline evaluation (Week 0). All interventions and baseline evaluation were conducted in 2019, at *Feldenkrais Praxis Athens* by the author. Each intervention week, as well as the baseline week, consisted of a self-report by the subject, followed by assessment with the NS tool (see Table 1). More precisely: During Week 0 (Baseline Week), the subject was first asked to describe any limitations she experienced in her everyday life. Next, Section I of the NS was performed by the practitioner at *Feldenkrais Praxis Athens*. Then, Sections II and III were performed in order to familiarize the subject with the required movement patterns. The practitioner's instructions for Sections II and III were recorded, so that the subject could repeat these sections at home for an entire week. The next week (Intervention Week 1), the subject came in and was asked to describe how she had experienced her home training. After this short self-reporting, Sections I, II and III of the NS were performed, appropriately modified by the practitioner according to the subjects' responses during the self-reporting. Again, instructions for Sections II and III were recorded as auditory cues for home training. All subsequent weeks of intervention (Weeks 2 to 5) followed the above-described pattern.

Results

In order to assess the easiness of use, the effectiveness, as well as the overall structure of the NS, we applied it to a selected patient and recorded the outcomes in a detailed manner:

Baseline evaluation/intervention

Baseline evaluation/intervention at Week 0 consisted of a short self-report by the subject and an evaluation with the NS. During the self-report – the first of the entire procedure –, the subject described that in her everyday life she encountered constraints in terms of her perception-action, interoception and responsiveness to environmental stimuli. Next, during Section I of the NS, which lasted 40 minutes and focused primarily on the control between dorsi and plantar flexion, the subject presented intense spasticity (on a grading scale of 0 to 2, she scored a 2; see Appendix A for a detailed description of the grading used for spasticity) and very strong sensory disturbances (Table 2, column "Week 0", Section I). During Section II, focus was given on a specific ATM sequence, termed "Balancing between sitting and lying #1" [31]: The subject was asked to connect movement with gravity, by prompting her to find on her own some means of support. She was reminded that every movement should start by pushing through the heels. She was thus asked to balance while moving from supine to sitting position and while rolling from left to right, or vice versa. Overall, she showed limited response to the rehabilitative process of Section II (e.g., inadequate spatial orientation, totally uncontrolled basic functional organization, perturbed breathing patterns, etc.; see Table 2, column "Week 0", Section II). At the beginning of Section III, the subject was asked to walk a distance of 4 m, which she covered in 8,84 sec. She also exhibited severe unsteadiness during walking; she was unable to maintain her balance during the swing phase of her walking. At the end of Section III, the subject was asked to select a favorite song, which brought about good memories: While listening to it, she was asked to perform a short "choreography" by moving freely in the space and changing her direction, rhythm, timing, and balance control according to the melody. Notably, ATM movement sequences "balancing between sitting and lying" ATM #1, together with the choreography lasted 24 minutes. In the end, all instructions for Sections II and III were recorded in the form of auditory cues

Table 1: The Neuroplasticity Scale (NS) evaluation tool. For a full description of each indicator, refer to Appendix A.

Indicator	Description	Evaluation
Section I: Exploratory manipulation during functional integration (FI)		
1. Sign of Babinski		On/Off
2. Spasticity grading scale	In certain movement patterns	2/1/0
3. Sensory disturbances		(on a 0-10 scale)
a. Fatigue		
b. Tingling sensations		
c. Numbness		
d. Limb weakness		
e. Other		
4. Hyperreflexia		On/Off
Section II: Awareness Through Movement (ATM) sequences		
1. Perception/Action		
a. Spatial orientation	Heading to specific directions	Able/Unable
b. Cognitive ability to perceive time and change rhythm during action		Uncoordinated/Moderately Coordinated/Movement Viscosity
c. Confusion during action (sadness, anger, fear, doubt, discomfort, body parts' recognition)		Impeded/Fluid Action – Controlled/Uncontrolled
d. Coordination of visionary, auditory and motor cues		
		Able/Unable
e. Tactile perception	FMTA (Facilitated Movement Through Attention), INH MOV (Inhibited Movement)	
		INH MOV/FMTA
f. Alternation between internal-external attention circuits		
		On/Off
2. Scanning measurement		
a. Use of internal maps to simulate movement without execution		On/Off
b. Sensing tonus and asymmetries		
		Able/Unable
3. Basic functional organization		
a. Flexion		
b. Extension		Controlled/Uncontrolled
c. Side bending		
d. Rotation		
e. Counter rotation		
4. Signs of optic neuritis		
a. Eye fatigue/pain during movement		On/Off
b. Reduction of visual acuity/visual field		On/Off
c. Eye movement difficulties		
		Lack of eyeball rotation/Moderately controlled/Eyeball coordinated movements

5. Respiration		
a. Breathing rate		Increased/Decreased
b. Holding patterns during inhalation/exhalation/pauses		Impeded/Improved
6. *Swallowing activation*		On/Off
Section III: Reference actions (walking, standing, sitting)		
1. Walking speed	Time needed to complete a 4m distance	sec
a. Shortening length of stepping		On/Off
b. Increasing of double leg support		On/Off
c. Decreasing of single leg support		On/Off
d. Swing time dynamics		Stable/Unstable
2. Counter balance		
a. Time of standing position		min
b. Side-by-side standing		Held/Held >10 sec
c. Tandem stand		Unable/5 sec/10 sec
3. Dynamic sitting position		
a. Orbiting and moving around a support base		Able/Unable

and given to the subject so that she would perform them daily for the entire week. Of note, in Section III, special focus was given on the clearance of left foot swing phase during walking and forward propulsion.

Intervention week 1

The following week – Intervention Week 1 –, several indicators in all three Sections of the NS showed a slight improvement (Table 2, column "Week 1"). More specifically: During Section I, which lasted 40 minutes and focused on reducing spasticity and controlling flexion and extension, the subject showed significantly less intense sensory disturbances, as well as reduced spasticity (score = 1), compared to Week 0 (Table 2, column "Week 1", Section I). Next, prior to initiating Section II, the practitioner clarified several instructions for specific ATM sequences, which seemed to have been misinterpreted or falsely executed by the subject during home training and highlighted the importance of minimizing motor range and effort and focusing on breathing, in order to better coordinate movement sequences. Section II was then performed in a 21-minute session. Several indicators showed improvement (for instance, the subject was able to spatially orient herself, to moderately control basic functional organization, etc.; Table 2, column "Week 1", Section II). Improvement was also seen in Section III, which lasted 15 minutes: The subject walked a 4 m distance in about half the time she did during Week 0 (4,90 sec vs 8,84 sec) and was able to orbit around a support base (Table 2, column "Week 1", Section III). However, she still showed signs of significant balance unsteadiness: She continued to present shortened stepping length and had difficulty in supporting herself on one foot in order to move the other. The subject also showed motor improvement during choreography; in fact, she mentioned that, whenever possible, she had started coupling some of her the daily activities with music and dance, following the recorded instructions about rhythm change, speed alternation, backward stepping and rotation changes.

Intervention week 2

During Section I, which lasted 28 minutes, the subject showed no spasticity (score = 0), but her sensory disturbances were back to maximum levels (Table 2, column "Week 2", Section I). In fact, the subject mentioned that during home training over the past week, her effort was uncontrolled, and her pain and discomfort were extreme. It was thus chosen to control pain and discomfort by minimizing the flexion and extension motor pattern range in different areas of the body. During Section II, which lasted 29 minutes, all indicators were found identical to those measured during Week 1, except for the following: Confusion during action was again evident, flexions and extensions were uncontrolled, and breathing rate seemed increased (Table 2, column "Week 2", Section II). Hence, for home training, focus was given on the five-foot digits' lifting, especially the role of the fifth digit in walking and balancing. A modified version of ATM #446 entitled "Ideal bending" was selected for practice (in this ATM sequence, the subject lies in supine position and is asked to lift the fifth foot's digit, while simultaneously dragging the heel against the floor; the purpose is to eventually bend the knee, using the foot digit as the "driving force", while flexing her thoracic spine) [32]. During Section III, which lasted 9 minutes, the subject showed slightly increased walking speed (she covered a 4 m distance in 4,40 sec, whereas she'd covered it in 4,90 sec during Week 1). All other balance parameters, however, remained unchanged compared to Week 1, except for two: Stepping length shortening and double length support were absent (Table 2, column

"Week 2", Section III). Gait training was thus performed, in order to clarify the role of foot mobility, pelvis back and forth movement, propulsive force, cadence and swing during walking. In the choreography that followed, gait training was incorporated: Through verbal instructions, the subject was prompted to differentiate her toes while finding her midline, weight shifting and rotating.

Intervention week 3

During the short self-assessment that preceded NS evaluation, the subject was able to clearly identify that her breathing abnormalities were associated with her spasticity and instability, and that her divided attention affected her balance, spasticity, and pain. During Section I, which lasted 34 minutes, the subject showed reduced spasticity (score = 1), as well as reduced lower back pain (Table 2, column "Week 3", Section I). Because of what the subject had observed in relation to her breathing, ATM #17, termed "Breathing" [33], was performed in order to help maximize her exhalation phases in supine and side-lying position; emphasis was given to alternate between the chest and the abdomen while breathing (inhaling/exhaling) and to activate the swallowing process, so as to decrease sympathetic nervous activation and increase parasympathetic relaxation response. It should be noted here that the reason for which an ATM sequence was incorporated during Section I is that the subject's clear ability to mentally connect her breathing abnormalities to her movement difficulties provided "fertile ground" for the practitioner to act upon and smoothly transition to the next section. During Section II, which lasted 29 minutes, the subject showed controlled basic functional organization (flexion, extension, side-bending, rotation, counter rotation), decreased breathing rate, improved breathing patterns and swallowing activation (Table 2, column "Week 3", Section II). It was thus decided to incorporate ATM #446 ("Ideal bending") and ATM #17 ("Breathing") in this week's home training, in order to further reduce pain and discomfort. During Section III, which lasted 13 minutes, no significant changes were observed in the indicators that were evaluated, compared to Week 2 (Table 2, column "Week 3", Section III). Gait training was performed in order to introduce pelvis movement during walking.

Intervention week 4

During the self-report that preceded NS evaluation, the subject mentioned that, over the past week, she had experienced acute cervical pain, inability to support or orbit her head while sitting, discomfort during sleep, uncoordinated eye movements while turning the head and uncontrolled basic functional organization. During Section I, which lasted 37 minutes, her sensory disturbances were found to be increased and her actions were impeded when in discomfort; however, her spasticity was moderately controlled (score = 1; Table 2, column "Week 4", Section I). F.I. process was applied in sitting position, while the head was supported, and included extension/flexion reversibility in the thoracic and lumbar spine regions. During Section II, which lasted 19 minutes, the most notable change that was seen, compared to Week 3, was that all basic functional organization seemed once again uncontrolled (Table 2, column "Week 4", Section II). It was decided to perform ATM #146 [34] ("Bending the spine while sitting on a chair"), in order to prompt the subject to mobilize her C7-T1 spinal segment (cervicothoracic junction) along with her pelvis. During Section III, which lasted 10 minutes, no significant alteration was observed in comparison to Week 3: The subject's balance parameters remained unchanged, while she covered the 4 m distance in 4,40 sec – that is, she required slightly more time than she did the previous week. Balance sequences and choreography involved auditory cues for weight shift, aiming at highlighting the role of the eyes in spatial movement, as well as their use as an initiator of head mobilization in different directions.

Intervention week 5

During Section I (36 minutes) of the NS evaluation, the subject showed no spasticity at all (score = 0), as well as significantly reduced sensory disturbances (Table 2, column "Week 5", Section I). FI process was applied in supine, in side and in prone position; the purpose was to connect the head with the rest of the body, so as to correlate balance with head movement. During Section II (29 minutes), the subject showed –for the first time in five weeks– an ability to coordinate visionary, auditory and motor cues. Her basic functional organization was back to a controlled level, and her swallowing remained activated (Table 2, column "Week 5", Section II). ATM sequences (both in *Feldenkrais Praxis Athens* and intended for home training) were based on an ATM entitled "The head affects balance" [35], which involves circular head movements relative to the left and right foot during walking. In this sequence, focus was given to clarify the various foot parts that come into contact with the ground. Section III (17 minutes) revealed an overall improvement in all examined indicators (Table 2, column "Week 5", Section III). Importantly, the subject continued to show no signs of balance unsteadiness. Cross-leg standing position, as well as right and left cross-body movements at a fast and slow pace, were incorporated in balance sequences and in the choreography.

Intervention week 6

During Section I (40 minutes), the subject showed no spasticity at all (score = 0), and minimal sensory disturbances (Table 2, column "Week 6", Section I). The practitioner performed FI process focusing on spine twisting, with pelvis, chest and head coordination. All indicators evaluated in Section II (21 minutes) were found to be improved (Table 2, column "Week 6", Section II). Movement sequences (starting from the sitting position) during this section aimed at restoring any missing cognitive links in flexion and extension, right and left turning and midline crossing. During Section III (19 minutes), all examined indicators showed an improvement: The subject's walking speed was increased (she covered a 4 m distance in 3,42 sec) (Table 2, column "Week 6", Section III), and there were still no signs of balance unsteadiness. Finally, all six weeks' choreography sequences were combined in one, which was performed by the subject at *Feldenkrais Praxis Athens* and videotaped by the practitioner. Thereafter, using this videotaped material, the subject was asked to execute the choreography on a daily basis, for as much as she could.

Table 2: Results shown by the subject at Baseline Week (Week 0) and all throughout Intervention Weeks 1 - 6.

	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Section I: Exploratory manipulation during functional integration (F.I.)							
1. Sign of Babinski	Off	Off	Off	Off	Off	Off	Off
2. Spasticity grading scale	2	1	0	1	1	0	0
3. Sensory Disturbances a. Fatigue b. Tingling Sensations c. Numbness d. Limb Weakness e. Other	10	3	10	5	7	3	1
4. Hyperreflexia	Off	Off	Off	Off	Off	Off	Off
Section II: ATM (Awareness Through Movement) sequences							
1. Perception/Action							
a. Spatial orientation	Unable	Able	Able	Able	Able	Able	Able
b. Cognitive ability to perceive time and change rhythm during action	Uncoordinated	Moderately coordinated	Moderately coordinated	Movement viscosity	Moderately coordinated	Moderately coordinated	Movement viscosity
c. Confusion during action (sadness, anger, fear, doubt, discomfort, body parts recognition)	Impeded Action	Controlled	Uncontrolled	Uncon-trolled	Impeded action	Controlled	Controlled
d. Coordination of visionary, auditory and motor cues	Unable	Unable	Unable	Unable	Unable	Able	Able
e. Tactile perception	INH MOV	FMTA	FMTA	FMTA	FMTA	FMTA	FMTA
f. Alternation between internal-external attention circuits	Off	Off	Off	On	On	On	On
2. Scanning measurement							
a. Using internal maps to simulate movement without execution	Off	Moderate	Moderate	On	On	On	On
b. Sensing tonus and asymmetries							
	Unable	Able	Able	Able	Able	Able	Able
3. Basic functional organization							
a. Flexion	Uncontrolled	Moderately controlled	Uncontrolled	Controlled	Uncontrolled	Controlled	Controlled
b. Extension	Uncontrolled	Moderately controlled	Uncontrolled	Controlled	Uncontrolled	Controlled	Controlled
c. Side-Bending	Uncontrolled	Moderately controlled	Moderately controlled	Controlled	Uncontrolled	Controlled	Controlled
d. Rotation	Uncontrolled	Moderately controlled	Moderately controlled	Controlled	Uncontrolled	Controlled	Controlled
e. Counter rotation	Uncontrolled	Moderately controlled	Moderately controlled	Controlled	Uncontrolled	Controlled	Controlled
4. Signs of optic neuritis							
a. Eye fatigue/pain during Movement	Off	Off	Off	Off	Off	Off	Off
b. Reduction of visual acuity/visual field	Off	Off	Off	Off	On	Off	Off
c. Eye movement difficulties	Lack of eyeball rotation	Lack of eyeball rotation	Lack of eyeball rotation	Moderately controlled	Lack of eyeball rotation	Eyeball coordinated movements	Eyeball coordinated movements

5. Respiration							
a. Breathing rate	Increased	Decreased	Increased	Decreased	Decreased	Decreased	Decreased
b. Holding patterns during inhalation/exhalation/pauses	Impeded	Impeded	Impeded	Improved	Improved	Improved	Improved
6. Swallowing Activation	Off	Off	Off	On	On	On	On
Section III: Reference actions (walking, standing, sitting)							
1. Walking speed	8,84 sec	4,90 sec	4,40 sec	4,20 sec	4,40 sec	3,40 sec	3,42 sec
a. Shortening length of stepping	On	On	Off	Off	Off	Off	Off
b. Increasing of double leg support	On	On	Off	Off	Off	Off	Off
c. Decreasing of single leg support	On	On	On	Off	Off	Off	Off
d. Swing time dynamics	Unstable	Unstable	Unstable	Unstable	Unstable	Stable	Stable
2. Counter Balance							
a. Time of standing position	<2	2	2	2	2	2	2
b. Side by side stand	Held	>10 sec	>10 sec	>10 sec	>10 sec	>10 sec	>10 sec
c. Tandem stand	Unable	5 sec	8 sec	10 sec	10 sec	10 sec	10 sec
3. Dynamic sitting position							
a. Orbiting and moving around a base of support	Unable	Able	Able	Able	Unable	Able	Able

Current Status of Subject

The patient's cranial nerve exam is essentially normal. In her motor exam, she is generally frail with a rather decreased muscle bulk. When examined in a seated position, her muscle tone in the lower extremities is only slightly increased symmetrically; but, given that the lower extremity muscle strength is 4-/5 to 4/5, from a functional perspective, it appears as if it is actually an insufficient tone of the type of spasticity that would better counterbalance her weakness. Her muscle tone in the upper extremities is now normal, and her muscle strength is 5/5. Her superficial and deep sensory exam are normal. She needs a cane; however, she is able to stand still, with her eyes closed, without using it. Cerebellar function tests are normal, although their evaluation is limited. Her current medications include: Fampridine 10 mg b.i.d. (since 2014), Citalopram 20 mg q.d., Venlafaxine XR 150 mg q.d., and vitamins. Importantly, as stated in the patient's last medical report, delivered by her neurologist in September 2022: "The patient has been following a therapeutic Feldenkrais protocol and a repetitive home training programme for years; I have seen her benefit objectively, far beyond her subjective evaluation of its beneficial effects. Whenever there is a functional worsening of her gait, by increasing the frequency of the sessions and complying better with home training guidelines, her daily functional performance improves impressively quickly. This [improvement] is usually more evident after a flu-like illness or because of sensitivity to heat in the summer."

Discussion

Most of the existing evaluation tools for MS are limited in terms of deciphering the motor-cognitive interface. On the other hand, there are functional MRI studies, which reveal neurological aspects that could be applied to FM and other movement practices, but their daily use by practitioners is not possible; and more importantly, their results have not been validated in non-resting state conditions (for instance see [36]). This prompted us to design a comprehensive, efficient, and easy-to-use assessment tool, the NS, which would take into account each individual's daily experiences and constraints and would therefore allow the practitioner to setup a personalized intervention, including a weekly home training programme for the subject.

Here, we applied our procedure to a single selected MS patient, in order to test the feasibility and efficiency of the NS approach as a proof-of-concept; in other words, to contextualize and analyze its use. Essentially, through repetition and weekly measurements of change, the NS was used to record brain learning in the context of rehabilitation. We found that the overall structure of our NS methodology enabled the subject to overcome her constraints during action, by triggering her learning ability and helping maintain her commitment to the rehabilitative process. During our six-week intervention procedure we saw that the subject developed self-awareness, through interoception and proprioception, and as a result showed optimal perceptual-motor adaptation. More specifically: By the end of Week 6, the subject showed no spasticity at all (score = 0); in addition, her sensory disturbances, although having fluctuated over the previous weeks, were practically absent (on a 0 to 10 scale, her disturbances were around 1). This is particularly important, as one of the primary problems she had when she came in for a baseline evaluation was her daily pain and fatigue. Moreover, already by Week 1, she showed ability to spatially orient herself, capacity to sense tonus and asymmetries and decreased breathing rate. Other indicators showed improvement later on; for instance, swallowing activation was evident by Week 3, while the ability to coordinate visionary, auditory and motor cues was evident only by Week

5. Notably, her basic functional organization (flexion, extension, side-bending, rotation, and counter-rotation) showed significant fluctuation: Such processes alternated between uncontrolled and controlled; in the end though, they were found to be controlled. Also, the subject's walking speed showed a rather constant increase over the six-week course: By Week 6, she was able to cover a 4 m distance in 3,42 sec, whereas at Week 0 she needed 8,84 sec to walk the same distance. More importantly, already by week 2, she showed no signs of balance unsteadiness – a status, which she thereafter maintained during all subsequent weeks.

We should note here that, importantly, although we originally designed the NS based on the described patient, we have subsequently applied our tool to another 20 patients (10 study patients, to whom NS was applied according to the described protocol, and 10 control patients, to whom no NS was applied) and have reported the relative results [37].

It is crucial to stress here that, in contrast to the EDSS and the BBS, in general, the NS does not attribute scores to individuals; rather, it offers a means to monitor an individual's responsiveness throughout the rehabilitative process by cultivating a sense of awareness that leads to functionality, and can hence be used to design, on a week-to-week basis, personalized interventions for patients. However, we do not wish to exclude the possibility of incorporating in the future some sort of scoring system in our method.

It should also be mentioned that the results presented here cannot be generalized for the time being; rather, they should be perceived as a means of evaluating the disease course of MS patients. Furthermore, one should keep in mind that brain learning cannot be assessed in terms of quantifiable improvement, since each patient displays different levels of sensory, perceptive, and motor amelioration.

Conclusion

Overall, our methodology highlights the importance of systematic evaluation for the establishment of better treatment in MS patients. The fact that our procedure involved repetitive home training and intervention, which changed on a weekly basis depending on the subject's responses and brain learning ability, reveals the significance of systematic assessment and constant adaptation of any motor-cognitive rehabilitative approach. The methodology we have designed clearly shows that a subject might respond to the same movement requirements in a different way every week; therefore, it is absolutely critical to monitor him/her closely, not only in clinical practice, but also by clearly asking him/her to express in his/her own words what he/she experiences on an daily basis.

Ideally, we should be aiming at adapting a treatment to the patient, rather than the patient to a treatment; hence, we believe that, with further refinement and expansion to multiple individuals, the NS – a novel, useful, efficient, and easy-to-use tool – could be used as a "platform" upon which MS rehabilitation can be based, both in clinical practice and in research

Acknowledgements

We would like to thank Dr. Marilena D. Papaioannou for editing the text.

Conflict of Interest

The author declares that she has no conflict of interest.

Informed consent

Informed consent was obtained from the patient involved in this study.

Statement of Human Rights

This study was conducted in accordance with the 1964 Declaration of Helsinki and its subsequent amendments.

Source of Funding

This study was self-funded.

References

1. Brodal P. 2016. The Central Nervous System, Fifth edition. New York, Oxford University Press.
2. Penner IK, Rausch M, Kappos L, Opwis K, Radü EW. 2003. Analysis of impairment related functional architecture in MS patients during performance of different attention tasks. *J Neurol* 250(4): 461-472. https://doi.org/10.1007/s00415-003-1025-0
3. Su K, Banker G, Bourdette D, Forte M. 2009. Axonal degeneration in multiple sclerosis: the mitochondrial hypothesis. *Curr Neurol Neurosci Rep* 9(5): 411-417. https://doi.org/10.1007/s11910-009-0060-3
4. Brañas P, Jordan R, Fry-Smith A, Burls A, Hyde C. 2000. Treatments for fatigue in multiple sclerosis: a rapid and systematic review. *Health Technol Assess* 4(27):1-61. https://doi.org/10.3310/hta4270
5. Langdon DW. 2011. Cognition in multiple sclerosis. *Current Opinion in Neurology* 24(3): 244-249. https://doi.org/10.1097/WCO.0b013e328346a43b
6. Nortvedt MW, Riise T, Myhr KM, Nyland HI. 2000. Quality of life as a predictor for change in disability in MS. *Neurology* 55(1): 51-54. https://doi.org/10.1212/WNL.55.1.51
7. Fjeldstad C, Pardo G, Frederiksen C, Bemben D, Bemben M. 2009. Assessment of postural balance in multiple sclerosis. *Int J MS Care* 11(1): 1-5. https://doi.org/10.7224/1537-2073-11.1.1
8. Sosnoff JJ, Shin S, Motl RW. 2010. Multiple sclerosis and postural control: the role of spasticity. *Arch Phys Med Rehabil* 91(1): 93-99. https://doi.org/10.1016/j.apmr.2009.09.013
9. Meyer-Moock S, Feng YS, Maeurer M, Dippel FW, Kohlmann T. 2014. Systematic literature review and validity evaluation of the Expanded Disability Status Scale (EDSS) and the Multiple Sclerosis Functional Composite (MSFC) in patients with multiple sclerosis. *BMC Neurol* 14: 58. https://doi.org/10.1186/1471-2377-14-58
10. Kurtzke JF. 1983. Rating neurologic impairment in multiple sclerosis: an expanded disability status scale (EDSS). Neurology 33(11): 1444-1452. https://doi.org/10.1212/wnl.33.11.1444
11. Berg K, Wood-Dauphine SL. 1989. Measuring balance in the elderly: preliminary development of an instrument. *Physiotherapy Canada* 41(6): 304-311. https://doi.org/10.3138/ptc.41.6.304

12. Çinar BP, Yorgun YG. 2018. What we learned from the history of multiple sclerosis measurement: Expanded Disability Status Scale. *Noro Psikiyatr Ars* 55(Suppl 1): S69-S75. https://doi.org/10.29399/npa.23343
13. Roxburgh R, Seaman SR, Masterman T, Hensiek AE, Sawcer SJ, et al. 2005. Multiple Sclerosis Severity Score: using disability and disease duration to rate disease severity. *Neurology* 64(7): 1144-1151. https://doi.org/10.1212/01.WNL.0000156155.19270.F8
14. Thompson AJ, Hobart JC. 1998. Multiple sclerosis: assessment of disability and disability scales. *J Neurol* 245(4): 189-196. https://doi.org/10.1007/s004150050204
15. Bagert B, Camplair P, Bourdette D. 2002. Cognitive dysfunction in multiple sclerosis: natural history, pathophysiology and management. *CNS Drugs* 16(7): 445-455. https://doi.org/10.2165/00023210-200216070-00002
16. Leisman G, Moustafa AA, Shafir T. 2016. Thinking, walking, talking: integratory motor and cognitive brain function. *Front Public Health* 4: 94. https://doi.org/10.3389/fpubh.2016.00094
17. Salamone PC, Esteves S, Sinay VJ, García-Cordero I, Abrevaya S, et al. 2018. Altered neural signatures of interoception in multiple sclerosis. *Hum Brain Mapp* 39(12): 4743-4754. https://doi.org/10.1002/hbm.24319
18. Ross E, Purtill H, Uszynski M, Hayes S, Casey B, et al. 2016. Cohort Study Comparing the Berg Balance Scale and the mini-BESTest in people who Have multiple sclerosis and are ambulatory. *Phys Ther* 96(9): 1448-1455. https://doi.org/10.2522/ptj.20150416
19. Givon U, Zeilig G, Achiron A. 2009. Gait analysis in multiple sclerosis: characterization of temporal-spatial parameters using GAITRite functional ambulation system. *Gait Posture* 29(1): 138-142. https://doi.org/10.1016/j.gaitpost.2008.07.011
20. Vrantsidis F, Hill KD, Moore K, Webb R, Hunt S, et al. 2009. Getting grounded gracefully: effectiveness and acceptability of Feldenkrais in improving balance. *J Aging Phys Act* 17(1): 57-76. https://doi.org/10.1123/japa.17.1.57
21. Stephens J, Call S, Evans K, Glass M, Gould C, et al. 1999. Responses to ten Feldenkrais awareness through movement lessons by four women with multiple sclerosis: improved quality of life. *Physical Therapy Case Reports* 2(2): 58-69.
22. Berthoz A. 2000. The Brain's Sense of Movement. Cambridge, Harvard University Press.
23. Damásio A. 2000. The feeling of what happens: body and emotion in the making of consciousness. Boston, Mariner Books.
24. Feldenkrais M. 1972. Awareness through movement: health exercises for personal growth. New York: Harper & Row.
25. Buchanan PA. 2012. The Feldenkrais Method® of Somatic Education. In: Bhattacharya A (ed) A Compendium of Essays on Alternative Therapy. Intech Open, pp 147-172. https://doi.org/10.5772/30885
26. Doidge N. 2015. The Brain's Way of Healing: Remarkable Discoveries and Recoveries from the Frontiers of Neuroplasticity. New York, Penguin Books.
27. Connors KA, Galea MP, Said CM. 2011. Feldenkrais method balance classes improve balance in older adults: a controlled trial. *Evid Based Complement Alternat Med* 2011: 873672. https://doi.org/10.1093/ecam/nep055
28. Thornton AE, Raz N. 1997. Memory impairment in multiple sclerosis: a quantitative review. *Neuropsychology* 11(3): 357-366. https://doi.org/10.1037//0894-4105.11.3.357 `
29. Paul RH, Beatty WW, Schneider R, Blanco C, Hames K. 1998. Impairments of attention in individuals with multiple sclerosis. *Mult Scler* 4(5): 433-439. https://doi.org/10.1177/135245859800400506
30. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, et al. 1994. A short physical performance battery assessing lower extremity function: association with self-reporting disability and prediction of mortality and nursing home admission. *J Geront* 49(2): M85-94. https://doi.org/10.1093/geronj/49.2.m85
31. Questel A. 2009. ATM 1: Balancing Between Sitting and Lying #1. [CD-ROM]. Lucerne: Uncommon Sensing LLC.
32. Feldenkrais M. 2001. The Feldenkrais Method Awareness Through Movement Lessons. Volume 9, Part B. Paris: Feldenkrais Federation, pp 3029-3034.
33. Feldenkrais M. 1994. The Feldenkrais Method Awareness Through Movement Lessons. Volume 1, Part 1. Paris: Feldenkrais Federation, pp 97-102.
34. Feldenkrais M. 1996. The Feldenkrais Method Awareness Through Movement Lessons. Volume 3, Part B. Paris: Feldenkrais Federation, pp 969-973.
35. Reese M. 2004. The Head Affects Balance: Walking Awareness Through Movement. [CD-ROM]. San Diego: Feldenkrais Resources.
36. Verrel J, Almagor E, Schumann F, Lindenberger U, Kühn S. 2015. Changes in neural resting state activity in primary and higher-order motor areas induced by a short sensorimotor intervention based on the Feldenkrais method. *Front Hum Neurosci* 9: 232. https://doi.org/10.3389/fnhum.2015.00232
37. Reziti T. 2018. Effectiveness of the Feldenkrais method in multiple sclerosis symptoms. The Conference on Movement and Cognition at the Joseph B. Martin Conference Center, Harvard Medical School, Boston, MA, USA.