THE MCS (MECHANIC, CYBERNETICS AND SYNERGETICS) METHOD IN VESTIBULAR REHABILITATION

Prof. Dr. Antonio.Cesarani (1)  
Prof. Dr. Dario Alpini (2) Prof. Dr. Saverio Capobianco (3)

1. ENT DPT.university of Milan, via F. Sforza 35, 20100, Milan, Italy  
e-mail antonio.cesarani@unimi.it  
2. Otoneurology Service Scientific Institute S.Maria Nascente don C. Gnocchi Foundation, Milan  
e-mail dalpini@dongnocchi.it  
3. ENT Dept.University of Sassari via Mancini 5, Sassari, Italy, e-mail savacap@uniss.it

ABSTRACT

Vertigo and dizziness are conscious symptoms and the disturbances are not disequilibrium or nystagmus but the consciousness of disequilibrium and nystagmus. Thus physical rehabilitation must not only be pointed to resolution of objective disorder but it must be aimed to resolution of subjective consciousness of the disorder itself.

MCS is the acronym of mechanic, cybernetics and synergetics. We said that to prepare a particular protocol of treatment is necessary to have in mind a particular model of the Equilibrium system.

Under a mechanic point of view we can consider the Equilibrium function as the result of the sum of these reflexes, the contemporary but distinct activation of some or all of these reflexes, according to the need: gaze, standing, walking.

Under a cybernetics point of view all the structures, peripheral and central, that contribute to the BOR and BSR constitute a system. A System is a network of different structures interconnected, interacting to reach a common goal. In this case the goal is human balance. The structures that provide the BOR and the BSR constitute the so-called Equilibrium System. Lackner remembered that the so-called vestibular nuclei are real polysensorial relays and that they are not only correlated to the activity of the vestibule. Thus it is uncorrected to define those nuclei as vestibular nuclei. They are true Balance nuclei that act together cerebellum and reticular formations to provide the sub-cortical component of human Equilibrium. Under the neurophysiological point of view the Equilibrium system (ES) is the Vestibular system. In order to reduce misinterpretation we propose to refer to the Equilibrium System comprehending also the vestibular part of informations and reflexes.
**Synergetics** model is based on the papers of Haken. He proposed his model to simplify complex functions such as macroeconomics processes, some physics phenomena such as clouds formation and many other complex phenomena. He proposed that every phenomenon, every function, is the macroscopic result of microscopic arrangements of the components that acts together to produce the phenomenon itself (that is to perform the function). By this point of view a system can be subdivided into different functional levels. Each lower, microscopic, level is directly communicating and interconnected with the upper, macroscopic, level.

**KEY WORDS** vertigo, dizziness, vestibular rehabilitation

**INTRODUCTION**

Vertigo and dizziness are symptoms very common in population. Some statistical researches state, for example, that they have a prevalence ranging from 5 to 10%, according to different age classes, they are particularly common in population over 40 years of age, they are the first reason for a medical visit in patients over 65 years.

There are no specific drugs for the treatment of these symptoms and there are no specific treatment for the major part of the causes of vertigo and dizziness. Rehabilitation seems to be the most effective tool for therapy of vertigo and dizziness. Although the so-called vestibular rehabilitation, that is a special rehabilitation of motion intolerance and imbalance problem, has only recently gained wide attention, the concept of head, body, and coordinated eye exercises as a treatment for vestibular disorders is actually over 50 years. As far back as the mid 1940s, an English otolaryngologist, sir Cawthorne, observed that some patients who experienced dizziness did better or recovered sooner when performing rapid head movements. In cooperation with a physiotherapist, Cooksey, he developed a regimen of exercises which, with some modifications, are frequently still used today. Cawthorne-Cooksey protocol is based on the concepts of habituation and sensory substitution. These concepts are correct but they are not univogue and, maybe, they are not the most important to explain the therapeutic effects of vestibular rehabilitation.

Vertigo and dizziness are conscious symptoms and the disturbances are not disequilibrium or nystagmus but the *consciousness* of disequilibrium and nystagmus. Thus physical rehabilitation must not only be pointed to resolution of objective disorder but it must be aimed to resolution of subjective consciousness of the disorder itself.

Such a particular kind of treatment need a particular theoretical basis. This is the reason why we structured our method of rehabilitation on a particular model of the vestibular system.

The first consideration that moved us to propose the following model was the need of thinking about a clear and satisfactory definition of Equilibrium.

According to Massion, Equilibrium control is correlated to postural control. Postural control is a behaviour that involves “the maintenance of the alignment of body posture and the adoption of
an appropriate vertical relationship between body segments to counter-act the forces of gravity and allows the maintenance of upright stance”. According to Norrè, balance function “consists of a sensori-motor complex. The goal of this function is: stabilization of the visual field and maintenance of the erect standing position”.

Both these two important concepts don’t explain, in our opinion, the ultimate goal of this sensori-motor complex. Why it is necessary stabilization of the visual field or maintenance of the upright stance? Why balance “works in a sub-conscious way and in normal conditions a “well-feeling” is present rather than a detailed perception of every change”?

In our opinion the sensory-motor complex that control balance, that we name Equilibrium system, is aimed to allow to animal man to be a *man*, that to say interacting into the environment, communicating with the environment and learning from the environment. Into, with, from are the keys to understand the reason why the vestibular system is so complicated and equilibrium is so important for animals, in general, and for man, in particular. Into, with, from are the practical keys of the exercises we will propose.

**PRINCIPLES OF MCS METHOD**

Why we named our rehabilitation protocols *MCS* method?

The answer is the model. *MCS* is the acronimus of mechanic, cybernetics and synergetics. We said that to prepare a particular protocol of treatment is necessary to have in mind a particular model of the Equilibrium system.

It is important to state the difference between model and theory. We don’t want to present a new theory regarding the vestibular system but an innovative interpretative model of the equilibrium function. In fact, under an epistemologic point of view, *theory* is a complex of logical argumentations that it is as valid as it is *true*. *Model* is a complex of logical argumentations that it is as valid as it is *useful*. In this way we prepared a model aimed to the treatment of vertigo and dizziness, using informations based on modern neurophysiology theories of the vestibular sistem, the movement control, the cognitive processing and learning.

The basis of every complex function is a reflex. Regarding the Equilibrium function, reflexes can be subdivided in two groups:

- ocular reflexes: vestibulo-ocular reflex (VOR), optokinetic reflexes (OKR), cervico-ocular reflexes (COR). These reflexes are aimed to the stabilization of the visual field

- spinal reflexes: vestibule-spinal reflexes (VSR), vestibule-collic reflexes (VCR), cervico-collic reflexes (CCR) cervicospinal reflexes (CSR) stretch reflexes (SR). These reflexes are aimed to the maintenance of upright stance and maintenance of postural control during moving (walking, stepping, jumping,...)
Under a \textit{mechanic} point of view we can consider the Equilibrium function as the result of the \textit{sum} of these reflexes, the contemporary but distinct activation of some or all of these reflexes, according to the need: gaze, standing, walking.

The neurophysiological organization of these reflexes are not always well distinguishable each from other. Frequently peripheral information, such as visual or labyrinth inputs, convey on the same vestibular nuclei or the same reticular formation. Lackner stated that, under natural conditions, during movement, is not possible to activate only single peripheral input. Thus Norrè proposed to distinguish two complex reflexes each controlled from different sensorial inputs but generally elaborated in the vestibular nuclei and cerebellum: the Balance Ocular Reflex (BOR) and the Balance Spinal Reflex (BSR). The principle of this classification is the interaction between different sensorial inputs and different site of elaboration.

Under a \textit{cybernetics} point view all the structures, peripheral and central, that contribute to the BOR and BSR constitute a system. A System is a network of different structures \textit{interconnected}, \textit{interacting} to reach a common goal. In this case the goal is human balance. The structures that provide the BOR and the BSR consitute the so-called Equilibrium System. Lackner remembered that the so-called vestibular nuclei are real polysensorial relais and that they are not univoquely correlated to the activity of the vestibule. Thus it is uncorrected define those nuclei as vestibular nuclei. They are true Balance nuclei that act together cerebellum and reticular formations to provide the sub-cortical component of human Equilibrium. Under the neurophysiological point of view the Equilibrium system (ES) is the Vestibular system. In order to reduce misinterpretation we propose to the Equilibrium System comprehending also the vestibular part of informations and reflexes.

A system is defined as any collection of components arranged and interconnected in a definite way, any collection of communicating materials and processes which together perform some function.

By this point of view labyrinths, eyes, vestibular nuclei, paravertebral receptors, antigravitary extensory muscles, plantar receptors,... constitute a system that performs the equilibrium function: the Equilibrium system.

Systems are generally grouped into five main categories regarding their different cybernetics aspects:
1) Lumped systems: the physical dimensions of the elements are very small compared to the wave length of the input-output quantitaites. The system is distributed
2) Time invariant systems and time varying systems: the system is time invariant if the elements of the system don’t change their values with time, otherwise the system is time varying
3) Linear systems: these must meet the homogeneity and superposition criteria and the operators for input-output relation are independent of both input and output quantitaties. Other systems are “nonlinear”
4) Causal systems: a system which does not give any output unless an excitation is applied to its input is so defined. Otherwise a system is “uncausal”:

5) Passive systems: in such system all the elements are passive. If there are dependent or independent active elements or energy sources, the system is active.

The behaviour of any system is determined by:

- the characteristics of the component or subsystems (e.g. threshold of stimulation of gamma-motoneurons, or characteristic of endolymph)
- the structure of communication between components, which usually involves feedback paths (e.g. internuclear vestibular connections, cerebello-vestibular inhibitory pathways)
- the input signals or variables to the systems initially assumed to be independent variables under the investigator’s control.

The ES, according to cybernetics, can be defined as a complex, open, causal, time-varying system. It is complex because it comprised of different subsystem and it is controlled by different laws. Functional characteristics of the ES are the same as the complex systems in general and its rules are the same of those of the complex open systems: knowledge of these rules is the corner-stone of the therapeutic strategy for every kind and site of lesion.

The ES is ruled by the following laws:

Totality: every component of the system correlates with the other components. In this way a modification of one component has effects on the other parts and on the whole system: for example a modification of the proprioceptive inputs may modify the vestibulo-ocular reflex and modification of the center of gravity may modify the activity of antigravitary lower limb muscles.

Feedback: every open system is a circular system in which the outputs (eye movements, head movements, antigravitary contractions,...) of the system act as input themselves: muscle activity is itself a proprioceptive input to the system that control the effectiveness of equilibrium output. (so-called reaferrence)

Equifinality: in a circular self-regulated system the same functional effect can be obtained by means of action of different components or different arrangements of system components. This is the cybernetics basis for sensory substitution compensatory phenomena during the course of a vestibular lesion. Balance is maintained using different sensorimotor strategies in different persons and/or in different condition. The same balance results are obtained both in normal subjects and in compensated vestibular patients when the interrelations between the different components of the system have been modified.

Calibration: a system is steady if the components of the system remain within personally defined limits. This is the cybernetics explanation of symptomatology threshold that may be different in different patients. By the cybernetics point of view we can state that, generally speaking, pharmacotherapy mainly acts modifying the calibration limits of the system.
Preference: each ES is preferentially arranged in a precise and “personal” sensorimotor organization. Each subject maintains his antigravitary position using preferentially visual, vestibular, proprioceptive or somatoesthesic inputs. During rehabilitative treatment, exercises have to be planned following preferential sensorimotor strategies, if they are again effective for balance maintenance, or in order to modify sensorimotor preferential strategies if the “natural” condition becomes (causing for diseases) uneffective.

Redundance: the ES is based on redundant sensorial inputs (visual, proprioceptive, vestibular, somatoesthesic) and redundant motor programs (motor redundance). Especially in aged patients symptoms are often due to a reduction of redundance level both in sensorial or in motor aspects. Treatment have to be aimed to increase redundance teaching how to use residual sensorial information and how to optimize residual motor skills.

Cybernetics laws allows to understand the complex organization of the ES but is not again sufficient to cover also cognitive aspects that, in human beings, underlay motor balance skills. Another model is thus necessary. When we treat a patients with vertigo or dizziness we have to keep in our mind that he/she is a human being. That to say that he/she presents consciousness of a disturbances of his/her ES. Disturbance itself and/or its consciousness prevents the patient to perform what he/she wants: standing, moving, lying, moving the head,...

It is thus necessary to have in mind a model that interconnects cognitive and movement aspects of human Equilibrium. At the same time the model must allow to simplify the evaluation of the patient and the comprehension of such a complex system like ES.

The brain, in fact, perceives sudden serial and intermodal integrated inner and outer stimuli and it programs coordinate reactions, physical and/or psychical. Perception ability is the functional basis of movement learning and it is sometimes more important than motor production skill. This is true especially for that particular motor skill named “equilibrium”.

Synergetics model is based on the papers of Haken. He proposed his model to simplify complex functions such as macroeconomics processes, some physics phenomena such as clouds formation and many other complex phenomena. He proposed that every phenomenon, every function, is the macroscopic result of microscopic arrangements of the components that acts together to produce the phenomenon itself (that is to perform the function). By this point of view a system can be subdivided into different functional levels. Each lower, microscopic, level is directly communicating and interconnected with the upper, macroscopic, level.

Equilibrium (that we can name E) is the macroscopic function. It is the result of the interaction of two main subfunctions: coordination and orientation.

Coordination concerns outself representation of the equilibrium while orientation concerns itself representation.
The level coordination (that we can name EA) is the result of the interactions of lower functional levels:

EAa: coordination of eye movements with head and body movements with respect to maintenance of continuous and distinct foveal vision

EAb: coordination of tonic antigravitary muscle contraction and gravity force in order to maintain the desired position and shape of body (the so-called posture)

EAc: coordination of tonic muscles contraction with gravity force and with dynamic phasic muscles contraction in order to obtain the desired movement (walking, jumping, running,...) into the environment

The level orientation (that we can name EB) is the result of the interaction of lower functional levels:

EBa: perception of the orientation of each part of the body with respect to each other part (perception of the body shape)

EBc: perception of the orientation of the whole body with respect to the environment.

Vertigo and dizziness can be interpreted as the consciousness of an uncorrect interaction between different functional levels of the equilibrium system. Thus, treatment planning must be aimed to reach a correct and unconscious interaction between coordination and orientation, even if sometime problems seems related only to a part of the function.

MCS METHOD NAD VESTIBULAR REHAB

On the basis of MCS model different protocols for the different vestibular impairments have been prepared. The protocols have to be considered as guide-lines. In fact each treatment planning must be strictly designed around the characteristics and the diagnostic findings of that specific patient.

Some exercises are not original. Some instruments can be substituted with others like them. Otherwise it is important to underline that this part proposes which physical and instrumental exercises are useful to answer to mechanical and/or cybernetics and/or synergetics disorders of the equilibrium system of your patient.

Treatment is subdivided into different protocols specific for the most frequent situations that causes vertigo and dizziness. At the end of each part a paragraph is dedicated to how to maintain equilibrium by self-administrated exercise, at home, after a period of rehabilitation performed with the therapist. It is important to underline that these exercises must be personalized and based on the personal program of treatment and they can never substitute the period with the therapist. In our experience treating the patient only by the mean of home protocols failure is sure.

A very frequent disease such as Meniere syndrome is not represented in this parts. It is known that rehabilitation is not able to prevent vertigo attacks nor to reduce progressive hearing loss. When the disease is stable, frequently, patients complain dizziness and unsteadiness even if
acute attacks became very rare. In this case patients can be treated with the protocol shown in the paragraph “Uncompensated unilateral vestibular hypofunction”.

The aim of this method is not to prepare a protocol for every vestibular disorder but to show the guidelines of our rehabilitative method using some frequent imbalance problems as examples. It is important to underline that for each disorder and, specifically, for each patient, a specific program have to be planned and that this program have to be based on mechanic, cybernetics and synergetics aspects of the Equilibrium system of that specific patient.

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