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Case Report

Clinical Adjustments of Plantar Tactile Stimulations Induce Concordance into Auditory-Visuo-Tactile Sensory Modalities to Perform the Multisensory Integration on Specific Neuro-Developmental Disorders: Learning Disabilities (e.g. Dyslexia, Dysgraphia). A Case Report

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Abstract

Through the tactile Sens, podiatry and treatment with insoles are approved to evaluate the participation of the podal modality in the treatment of neuro-developmental disorders like sensory processing disorders and/or specific learning disabilities (e.g. dyslexia, dysgraphia). The quantitative assessments of the exteroceptive plantar sole participation were conducted with the clinical testing of the Proprioceptive Dysfunction Syndrome: the most contemporary of the multisensory integration/processing disorders in learning disabilities and in the large family of neuro-developmental disorders. The interactions on plantar tactile information and visuo-spatial and multisensory integration (audio-tactile sensory information on vision) are evaluated. The influence of the plantar modality on motor control, spatial localisation and sensory integration exposes the aim to obtain the concordance into all those sensory modalities to perform the sensory integration and then the learning capacities. The clinical reasoning leading to diagnoses of foot insoles and stimuli enabling all the auditory-visual sensory signals to be concordant are explained in order to make podiatric treatment as effective as possible in both sitting situations (the most frequent situation during school learning) and standing situations (motor learning).

Keywords: *Podiatry; Neuro Developmental Disorders; Sensory Integration Disorders; Sensory Processing Disorders; Proprioceptive Dysfunction Syndrome; Coherence Audio-Tactile; Dyslexia; Vertical Heterophoria Labile; Insoles; Multi-Sensory Integration*

Abbreviations

NDD: Neuro Developmental Disorders; SID: Sensory Integration Disorders; SPD: Sensory Processing Disorders; PDS: Proprioceptive Dysfunction Syndrome; LE: Left Eye; RE: Right Eye; PDN-6: Posturodynamic 6; VHL: Vertical Heterophoria Labile; VH: Vertical Heterophoria; VO: Vertical Orthophoria; L: Left; R: Right; B: Both (Left and Right); KFA: Active Knee Flexion Test; E: Equal; FM: Knee Flexion Deviated Medially; FL: Knee Flexion Limited; FC: Knee Flexion Centered and of Equivalent Amplitude Between the Two Knees

Introduction

This study focuses on the influence of plantar stimulation (insoles) to reduce sensorimotor dysfunctions and sensory incoherences (dys concordances) that affect multi-sensory integration (motor control; spatial localisation; audio-tactile interferences) on NDD and or SPD/SID, principally specific learning disabilities (e.g. dyslexia, dysgraphia) and PDS [1-3]. Insoles are part of clinical management of NDD, SID, PDS. Their reliefs modify the cutaneous sensitivity of the plantar foot surface (i.e. perception of plantar pressure on the ground) [4,5]. This perception of the plantar sensitivity is assumed to be influenced by cutaneous mechanoreceptors and their reflexive zones by inducing a variation of pressure either increasing or decreasing and then the fundamental transduction and transmission of tactile feedback of 1702 mechanoreceptors. Those mechanoreceptors and their reflex receptive fields induce and modulate muscular activation in response (e.g. muscular activity, variations in the distribution of muscle tone and proprioception (changes in muscle spindle activity)) [6-11]. The relief of the insoles increase pressure and generates repetitive impulses to induce depolarisation of the tactile receptor, leading to modulation of cortical excitability and depolarisation of the underlying brain regions. The efferent response inputs (sensory afferent signals with central inputs from efferent motor commands (i.e. corollary discharge is engaged)) active muscular chain [12]. The comparison on the efferent motor command execution and what is realized could be compared with the multi-sensory reafferention (i.e. concordance into all sensory signals or dys concordance into two or more sensory signals inducing sensory noise) [13]. when sensory noise is reduced with the multidisciplinary action to obtain the concordance of sensory information: optimisation of the perception of different modalities (visual, audio, tactile, proprioception, interoception…), multisensory integration: processes from a combination of peripheral sensory information's, is improved then the motor response (action) is more effective, thus reducing the learning deficit or delay [14,15].

Case History

We report the case of a 13-year-old male with recurrent NDD and specific learning disabilities (dyslexia) and PDS. scores of PDS questionnaire were = 112 (nocturne: 51; motor: 32; spatial dimension: 13; perception dimension: 16) [3]; scores of Adolescent/Adults Sensory Profile (questionnaire Dunn) were = 179 (sensitivity: 45; seeking: 53; avoiding: 27; registration: 54) [16]. He was examined by the medical team with the presence of a scoliotic attitude (Figure 1); forward offset of the scapulae in relation to the pelvis; hyper pression under the heel; centre of pressure on the right (1.45 mm); pressure distribution 55% on the left; Friedman score: grade 1; Mallampati score class 3. On the basis of the clinical examination, it was decided to fit active prisms (RE: 0.25 dioptric base 125°; LE: 0.75 dioptric base 55°) prior to the podiatric assessment [3]. We validate the podiatry proposition and then we realize the specific insoles.

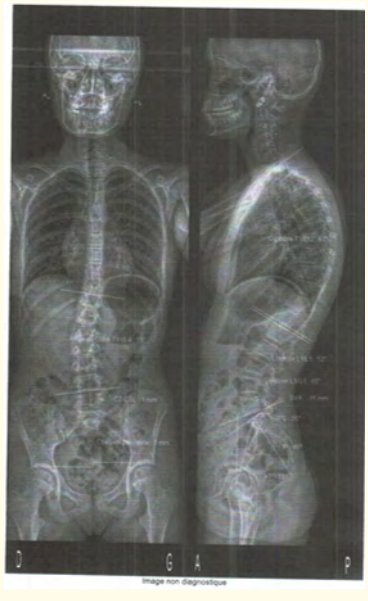

Figure 1*: Xray of the patient in the two plans.*

Materials and Methods

Clinical evaluation

The (main) clinical tests used are:

a) Evaluation of the localisation of the hypertonicity following the passive evaluation test of his internal rotation of the lower limb in response of a stimulus in the supine position (no involvement of his lower limb) in different conditions: control, with prisms and with plantar stimulation.

b) PDN-6 test: Voluntary movements of lateral inclination and one leg stance [17].

c) Perceptive Maddox: To evaluate the spatial localisation and the VHL [18-20].

d) Spatial localisation foot test.

Localisation spatial of the feet in different conditions to evaluate the representation of the feet position (also involving the lower limb): also involving the lower limb in correlation with the subject's internal reference (internal model, in a control situation, by modifying: afference (passive modification of the position of the feet), motor control (after a walk), by presenting an image of the position of the feet and reproducing it (comparison between visuo-perceptive and tactilo-perceptive (representation of one's body schema) and following a recall of a situation (activation of the recall in working memory). The difference between the position of the foot and that of the hand is evaluated in error steps: position superimposable between the position of the hand commanded by the subject and that of the foot (motor expression superimposable on perception); error: difference between the position of the foot and that shown by the hand (difference between perception and action). We report the results in table 1. Then, we validate the podiatry proposition, and we realize the specific insoles. The results are exposed in the last column of table 1.

	Control	With Prisms	With Prisms and Plantar stimulations or Insole
Head control (see straight on the top, hand on iliac spine)	R	E	E
Heal turn on left	L	E	E
Head turn on right	R	E	E
Eyes turn on left	R	E	E
Eyes turn on right	L	E	E
PDN-6 score up right (motor control (volontary mouvement))	111,117	111,112	101,102
Perceptive Maddox in sitting without plantar contact	VH	VO	not realisable
Perceptive Maddox in sitting with plantar contact (here plantar modlity induce spacial localsiation disorders)	VH	VH	VO
Localisation spatial of the foot: control imediatly	B (2)	L (1)	L (1)
Localisation spatial of the foot: feet positioned by the podiatrist (afferent cues)	R (1)	R (1)	0
Localisation spatial of the foot: after walking (efferent cues proprioception)	L (1)	L (1)	0
Localisation spatial of the foot: in regrading one imagerie of feet position (imagerie / reproduction)	L (1)	L (1)	L (1)
Localisation spatial of the foot: 2 forward positions must be recalled (N back -2 recal ; cognitive recall: working memory)	B (2)	L (1)	L (1)

Table 1: *Results of the clinical evaluations.*

L: Left; R: Right; E: Equal; PDN-6: Posturodynamic 6 (Score 0.0 to 117.117); VHL: Vertical Heterophoria Labile => VH: Vertical Heterophoria; VO: Vertical Orthophoria; B: Both (Left and Right; Error Score 2 Points; Left or Right; Error Score 1 Point).

In regard of those result although already good, because prism and prism+insole induce VO. This clinical condition where the ortho-localisation is obtained, we could verify the therapeutic proposal as a whole by assessing possible audio-tactile interference: dys-cordance or concordance (multisensory integration) that could affect the NDD children and dyslexia children [21-23]. We observed the influence of the proposed treatment on the sensory integration disorders by the "multisensory perception" the third dimension of the PDS [1-3,13,21-24].

The interference audio-tactile on multisensory integration is evaluated through the presence and the localisation of visual pseudo-scotomas (visual perception) induce by sounds 500Hz and 1000Hz [22-24]. We asked the subject to report any loss of visual perception and said where is/are localized in the conditions with prism + plantar contact and prism + insole.

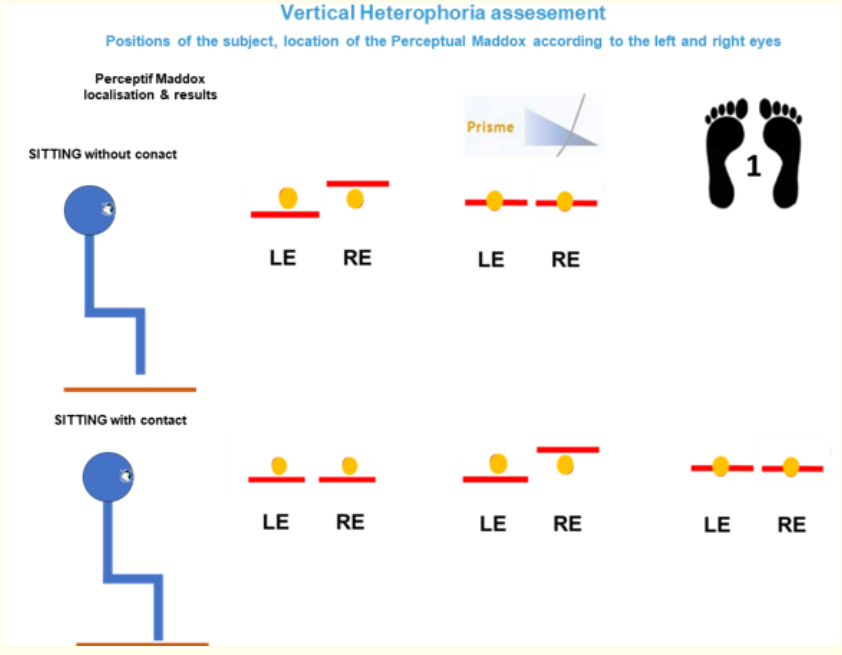

Figure 2: *Vertical heterophoria assessment depending on the patient positions with prims and the first insole proposition.*

LE: Left Eye; RE: Right Eye.

Also, our result seemed insufficient but not enough in regard of the NDD and multisensory integration, so we supplemented the clinical assessments with two specific tests [1-3,12-15]. The two specific tests are: 1) amplitude and direction of active knee flexion (KFA test). The KFA test is the clinical evaluation of the patella when the subject makes a knee flexion with the heel still on the ground. The evaluation is the deviation of the patella in medial or lateral plane and the comparison between the knees of the amplitude of the flexion (the flexion of one knee is limited in comparison of the other knee flexion) [25,26] and 2) the influence of the movement direction tests (influence of the proprioception) in supine position on the evaluation of the localisation of the hypertonicity (to completed the initial procedure of the clinical test).

We modified the insole with these indications. We added retro capital head of 1 and 2 of 2 mm on the right and left and a 4 mm arch stimulation to normalise the KFA test.

The influence of the movement direction tests on the muscular tone distribution [3,12-14]. It investigates binding mechanisms in the somatosensory-motor domain through the evaluation of the repartition of the muscular tone (motor response without voluntary motor features) depending on the stimuli localization. This present test clearly demonstrates binding between somatosensory stimulus and perceptual-motor coding levels all contribute to the neurophysiology of sequence learning [27,28]. Importantly this test is realized in supine position and the clinicians must be adapt the stimulation depending the organisation plane and the influence of the gravity field on motor control and multisensory integration [29].

According to the clinical result, the insoles were modified (see inside the table 2) and in regard of hand cross on the umbilic => foam to cover; arms stretched out behind the head => no cushioning or rebound at the heel.

	Control	With Prisms	With Prisms and Plantar stimulations or Insole	**modifications to insole with the clinical deductions of the two complementary tests**
Head control (see straight on the top, hand on iliac spine)	R	E	E	E
Heal turn on left	L	E	E	E
Head turn on right	R	E	E	E
Eyes turn on left	R	E	E	E
Eyes turn on right	L	E	E	E
PDN-6 score up right (motor control (volontary mouvement))	111,117	111,112	101,102	**1,002**
Perceptive Maddox in sitting without plantar contact	VH	VO	not realisable	**not realisable**
Perceptive Maddox in sitting with plantar contact (here plantar modlity induce spacial localsiation disorders)	VH	VH	VO	**VO**
Localisation spatial of the foot: control imediatly	B (2)	L (1)	L (1)	**0**
Localisation spatial of the foot: feet positioned by the podiatrist (afferent cues)	R (1)	R (1)	0	**0**
Localisation spatial of the foot: after walking (efferent cues proprioception)	L (1)	L (1)	0	**0**
Localisation spatial of the foot: in regrading one imagerie of feet position (imagerie / reproduction)	L (1)	L (1)	L (1)	**L (1)**
Localisation spatial of the foot: 2 forward positions must be recalled (N back -2 recal ; cognitive recall: working memory)	B (2)	L (1)	L (1)	**0**
active bending of the knees (feet on the ground)				
Left			**FM+FL**	**FC**
Right			**FM**	**FC**
hand cross on the umbilic	**L**	**R**		**E**
arms crossed over shoulders opposite arm	**E**	**E**	**stimulation on the heel**	**E**
arms stretched out on either side of the body	**L**	**L**	**left stimulation must be more longer than right**	**E**
arms stretched out towards the ceiling	**R**	**R**		**E**
arms stretched out behind the head	**L**	**E**		**E**
arms stretched out along the body	**R**	**R**	**stimulation of the heel on the hypertonic side ***	**E**

Table 2: *Results of the clinical evaluations where we had KFA and movement direction tests.*

*L: Left; R: Right; E: Equal; PDN-6: Posturodynamic 6 (Score 0.0 to 117.117); VHL: Vertical Heterophoria Labile => VH: Vertical Heterophoria; VO: Vertical Orthophoria; B: Both (Left and Right; Error Score 2 Points; Left or Right; Error Score 1 Point); FM: Knee Flexion Deviated Medially; FL: Knee Flexion Limited; FC: Knee Flexion Centered and of Equivalent Amplitude Between the Two Knees. *: Correlate with Xr figure 1.*

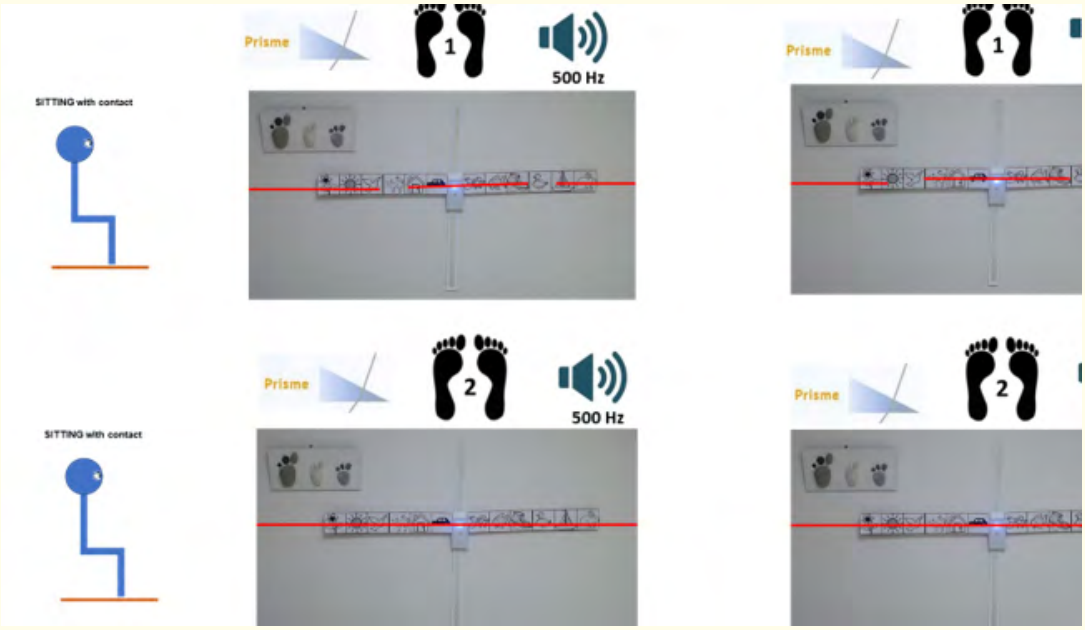

Figure 3: *Localisation of the pseudo-scotomas in siting position without and with contact on the ground with the audio stimulation (500 Hz and 1000 Hz) depending the therapeutics propositions prisms and insole 1: first proportion of insoles and prisms and insole 2: insole 1 modified with the results of KPA and movement direction tests. pseudo-scotomas is/are the disruption of the red line saw by the patient through the Perceptive Maddox realize at 4 meters (hold in the perception of some figure). representative image of the feet corresponds to the plantar orthoses. 1 being the orthoses at the beginning of the consultation. 2 being the plantar orthoses 1 which have been modified with the tests KPA and movement direction tests.*

The results are exposed by the to be concordant on the multisensory integration (auditory-visual sensory signals). The disappearance of pseudo-scotomas confirms the concordance into audio and tactile cues: reduction of audio-tactile interference: dys-cordance.

Discussion

Studies have established relationship between NND, SID, DPS and perception-action integration in multis sensory integration disorders (audio visuo tactile cues) [1,3,14-16,21,22,24,30,31]. We show first that perception-action level binding of this patient, the complementarity (prisms insole) induces some reduction of the disorders in motor control and spatial localisation in replicating the effects reported by the colleagues (See table 1) [3,15,16,30,31].

Also, we expose that it is not sufficient because sensory multi-integration, like in classroom to read copy or writing, still remains altered (increased) and underperforming (See figure 2 podiatrist treatment 1). Thus, visual and motor coding have a privileged role in the neurophysiology of sequence learning. Here, we propose to adapt the motor response by modify the afferent plantar sensory cues in

take care of the KFA and movement direction tests responses (stimuli-response translation clinical processes). We expose that perceptual and response codes contribute to the neurophysiological coding of sequential regularities and stability (prediction state, see figure 3 podiatrist treatment 2) [25-27]. This performs the motor control, the spatial localisation and perception/integration (the 3 domains of the SID and PDS) [3,14,15,18-23]. The new sensory situation coherence or compatible audio-tactile sensory information (sense and proprioception (reafferentation of efferent copy include)) produce perception-action integration processes and may be reduction of the sensory noise principally in dyslexia [30,31]. Those could help to the reduction of the learning deficit (NDD) because the perceptual - motor domains are sufficient to develop the representation of leaning sequential regularities.

Conclusion

In sum, we have shown evidence that perceptual, motor, and perceptual-motor coding levels all contribute to the multisensory integration. The first step to correct the couple perception-action of visuo and motor control is efficient but not completely effective, leaving the possibility of variation (sensory-motor lability) and therefore of sensory noise disrupting integration. motor symptoms, sensory processing has also been shown to be disturbed. However, a stable and performing integration of perception and motor processes is essential for the control of goal directed. That could affect the sequence learning. The clinical evaluations KFA test and the movement direction tests complementary to the initial assessment allow us to modify and adjust the treatment specifically to the subject and to limit (reduce) the sensory noise in inter modalities which will probably help the child and increase his school performance and reduce the delay in NDD [1,2,14,16,24,26,27,30,31].

The present study clearly demonstrates the binding between somatosensory stimulus and response features. This positive response must be obtained by and for several tests to confirm the positive convergence of sensory signals. The beneficial effect and success of decoding at the perceptual-motor level suggests that sensory modality-specific coding works in concert with modality-independent sequence learning.

Limitations of the Study

This is a clinical proposition. The clinicals testing is one proposed in the treatment of PDS one's of SID and or sensory processing disorders in the NDD family. All of those disorders could be in comorbidity between us and with other disorders. The role of the coding mechanisms of the 3-dimension characterizing the PDS could be observed with the overlap between the motor, the visuospatial and perceptual representations through the complementarity into the clinicals evaluations [1,2,14,27,28]. In all 3 cases, the neurophysiological representations of probability levels were stable, sustained, and could be generalized but it needs more study and anyway the clinicals observations and testing must be the "way of results" [20,22]. In those learning disorders the multidisciplinary must be privileged roles.

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Declaration of Patient

Thanks to the patient that the name was changed. Consent Written informed consent was obtained from the patient to publish this paper. Participation in the study adhered strictly to patient privacy. This report is registered: 2016-A01062-49-MJ062025.

Author Contributions

MJ designed the study and wrote the protocol like it used in clinical practice. The clinicals test was proceeded by MJ, prisms were realized by the optician in conformity of the prescription, insole and modifications were realized by MJ.

Conflict of Interest Statement

MJ declared no competing interest regarding the publication of this paper.

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