ORIGINAL RESEARCH

Improvement in Attention in Patients Undergoing Network Spinal Analysis: A Case Series Using Objective Measures of Attention

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ABSTRACT

Objective – Anecdotal preliminary evidence suggests that chiropractic care may be of benefits for individuals suffering from ADHD. This case series presents the improvement in attention experienced by 9 adult patients undergoing Network Spinal Analysis.

Methods – Nine adult patients are presented (4 male, 5 female) with a mean age of 40.4 years (range 22 – 58 years old). All patients were evaluated with the Test of Variable of Attention (TOVA) before receiving Network Spinal Analyis (NSA) care and at 2 months into care. The nine patients received level 1 NSA care for two months, as taught by the Association for Network Care. Neurospinal integrity was evaluated with palpation, as well as surface electromyography. Cognitive process of attention was objectively evaluated using a continuous performance test, the Test of Variables of Attention (TOVA).

Results: We evaluated our patient cohort before and after Network care using sEMG and variables from the continuous performance test (TOVA). Before care, all patients had an abnormal ADHD score with a mean of -3.74 (range: - 8.54 to - 1.89). After 2 months of care, all patients had a significant change in ADHD score (p=0.08) and 88% completely normalized the ADHD score. 77% and 66% of patients experienced significant change in reaction time and variability score, respectively. All patients experienced a significant reduction in sEMG pattern of activation (p=0.08). We discuss possible mechanisms by which spinal care may have enhanced the function of the prefrontal cortex, thereby resulting in improved attentional capacities

Conclusion – In this case series the nine adult patients experienced significant improvement in attention, as measured by objective outcomes, after receiving two months of Network Spinal Analysis. The progress documented in this report suggests that NSA care may positively affect the brain by creating plastic changes in the prefrontal cortex and other cortical and subcortical areas serving as neural substrate for the cognitive process of attention. These findings may be of importance for individuals suffering from attention deficit. Further research into this area is greatly needed.

Key words: *chiropractic, attention, Network Spinal Analysis, thalamocortical oscillations, subluxation*

Introduction

Attention is the cognitive process of selectively concentrating on one thing, while ignoring other things.[1] In 1890, American psychologist and philosopher William James wrote:

"*Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneous possible objects or train of thoughts. Focalisation, concentration, of consciousness are its essence.*"[2]

Despite this seemingly simple description, more than a century of research and the fact that attention is one of the most studied domains in psychology and neuroscience, a clear understanding and a uniformly accepted definition of the word are yet to emerge.[3] Attention has been defined in many ways and various subcategories have been created to further precise the concept [4] (see table 1). Gerschwind defined attention as the ability to maintain a coherent line of thought or action [5].

Despite those considerations, the nature of attention remains elusive. This is not surprising since attention is not a unitary faculty. Rather, it is a diversified faculty of the human cognitive system that is subserved by multiple interrelated attentional networks in the brain and manifests itself in a

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variety of types and at different levels in almost every aspects of human behaviour, from perception and motor control to working memory, skill acquisition, response selection and consciousness.[6] Some authors even hypothesize that attention plays an important role in consciousness [7].

Table 1 : Subcategories of attention (from Palmese [4])

1. Focused attention – the ability to focus one's consciousness on an object
2. Sustained attention – the ability to maintain the focus on the object
3. Selective attention – the ability to sustain attention in the presence of distracters.
4. Alternating attention – the ability to change mental set
5. Divided attention – the ability to simultaneously process two pieces of information at once.

If the theoretical underpinnings of attention are vast, clinically, attention has relevance to various domains since it is implicated in various disorders. The most common one is attention deficit / hyperactivity disorders (ADHD). Epidemiological studies suggest that between 3-10% of children and 1-6% of adult population in the United States suffers from ADHD [8]. The worldwide prevalence of ADHD is between 3% and 9% [9].

Deficit in attention is not only related to poor concentration. It can have devastating consequences on the daily functioning of individuals it affects. Individuals suffering from ADHD have been found to suffer from significant risk related to daily living (see table 2).

Table 2 : Increased behavioral risks in patients suffering from ADHD (adapted from Barkley [10])

- Having at least four or more serious accidents – three times the risk
- Having traumas requiring sutures or hospitalisations – twice the risk
- ADHD young adults have four time as many car accidents as controls
- Having two or more car crashes – seven times the risk
- Being at fault in accidents – four times the risk
- Receive four times more citations (esp. speeding and failing to obey stop signals)
- Increased risk of cigarette, alcohol or marijuana use – 2-3 times the risk
- Greater difficulty managing money and credit
- Failing a grade, being suspended or expelled from school – three times the risk
- Greater risk of not finishing school
- Greater risk of unprotected sex, teen pregnancy and acquiring sexually transmitted disease
- Greater risk of changing job or likelihood of being fired
- Increased likelihood of divorce

Disorder of attention can also be found in traumatic brain injuries, which affect 2 million individual every year in the United States [4]. Attention problem has also been linked to neurodegenerative disorders, such as dementia [52], Alzheimer's disease[53] and Parkinson's disease [52]. The neuroanatomy and neurophysiology of attention, as it relates to prefrontal cortex is reviewed in the discussion portion of this article.

Limited evidence exist that chiropractic care may benefit individual suffering from ADHD. In a single subject research design, Giesen suggested that chiropractic care was associated with behavioural and motor hyperactivity improvement in five of seven children [11]. Bastecki reported the remission of ADHD symptoms of a five-year-old child receiving chiropractic care.[12] So far however, no studies have linked chiropractic care to changes in objectively measured attentional capabilities in adults. This case series represent the first study of the changes experienced by adult patient receiving NSA utilizing objective measure of attention.

Methods

Technique - Network Spinal Analysis

Network Spinal Analysis (NSA) is an evidenced based approach to wellness and body awareness, developed by Donald M. Epstein, DC [13].

NSA evolved from subluxation-based, vitalistic chiropractic into a system of specific low force spinal applications designed to enhance the cognitive and precognitive awareness of an individual's spinal structure, body tension patterns, and the development of unique Somatopsychic and Respiratory waves of skeletal motor activity purported to assist in improved self-organization of the nervous system [14].

NSA care is delivered through a series of three levels of care. Each level has specific outcome and low force contact applications (see table 3). Low force contacts are taken at areas related to or adjacent of spinal-dural attachment. Those areas are known in NSA as Spinal Gateways. The application of force is guided by a clinical priority system called the Phasing System (see table 4).

Table 3 : Levels of Care in NSA and related anticipated outcomes

Level 1 – entrainment of respiratory motion with spinal motion (respiratory wave), release of tension from spinal stability subsystems, reduction of parameters of spinal cord tension.

Level 2 – resolution of dominant spinal defense patterns, development and refinement of the Somatopsychic wave (entrainment of two vertebral oscillators)

Advanced care – absence of defense posture, development of the third (thoracic oscillator).

Table 4 : NSA's Phasing system

Phase 1 - Sacrum or occiput
Phase 2 - C1 or C5
Phase 3 - sacral apex or ilium
Phase 4 - C2 or C3
Phase 5 - Scaral apex/C2 or Coccyx/C5

Based on research done with post-traumatic stress disorder (PTST) patients demonstrating decreased blood flow and activation of prefrontal cortex (especially on the right hemisphere) and activation of limbic structures (see for example Shin [15]), Network Spinal Analysis hypothesizes that repeated life stressful events in the face of inappropriate coping strategies result in progressive dys-activation of prefrontal cortical areas and activation of limbic system. Dys-activation of the prefrontal cortex is hypothesized to impair the brain's ability to pay attention to the body's internal processes, resulting in reduced body awareness and decreased ability to access internal healing resources

Since previous research has demonstrated that prefrontal cortical areas (especially in the right hemisphere) are part of a neural network subserving the cognitive process of attention (see neuroanatomy of attention in the discussion), we were interested in knowing whether NSA care could influence attentional capabilities in adults.

Clinical Features

During a three months period (March – May 2006), all new patients presenting to our wellness centre reporting a complaint of attention problems (either as a chief complaint or as an additional complaint) on our health intake questionnaire were given the possibility to enter our study. Out of a panel of 57 new patients, 10 patients reported suffering from attentional difficulties (17.54%). Three patients had attention deficit as a chief complaint, seven as additional complaints. One patient declined to participate in the study because she would not be able to comply with the 2 months of care due to moving away. Therefore, nine patients (4 male, 5 females) with a mean age of 40.4 years (range 22-58) participated in our study. Patient characteristics are presented in table 5.

All patients were also evaluated for neurospinal integrity using Epstein's model of neurospinal subsystems. Palpation was used to assess tone and compliance of the active and passive subsystem. Paraspinal surface electromyography and thermography was used to assess neural control system.

Since this type of palpation has never been tested for validity of reliability, in this study, we used surface electromyography (Insight Subluxation Station – Millenium, Chiropractic Leadership Alliance) as our main outcome for neurospinal integrity. Static paraspinal surface electromyography using Insight Subluxation Station has recently been shown to have excellent intra- and inter-examiner reliability.

Table 5 : Patient characteristics

Subject	*Age*	*Gender*	*Presenting complaint*
1	29	M	Spinal pain
2	47	F	Digestive/Gastrointestinal
3	47	F	Migraine headaches
4	34	F	Concentration/memory problems
5	58	M	Concentration difficulties
6	27	M	Medically diagnosed ADHD
7	49	F	Fibromyalgia
8	50	F	Whiplash / Traumatic Brain injury
9	22	M	Fatigue / anxiety

All patients also underwent chiropractic functional neurological evaluation of the neuraxis, as taught by the Carrick Institute for Graduate Studies. Examination included sensory, motor, balance and oculomotor function assessment.

All patients were evaluated using the visual portion of the Test of Variable of Attention (TOVA). The TOVA is 22.5 minutes objective, standardized, visual continuous performance test of attention. It is a non-language based computerized test requiring no right-left discrimination and has negligible practice effect. The TOVA has been shown to have good sensitivity and specificity in discriminating ADHD from normal control individuals [16].

During the test, one of two easily discriminated visual stimuli is presented for 100 msec every 2 seconds. The designated target is presented randomly on 22.5% of the trials during the first half of the test and randomly on 77.5% of the trials during the second half. These two test conditions examine attentional variables under the usual stimulus infrequent mode (first half of the test) and impulsivity in the more provocative stimulus frequent conditions (second half of the test). Subject press a microswitch as quick as they can when the designated target appear but ignore the non-target. A 2.5 minutes practice session is administered to insure the subject understand the instructions. Measures of performance on the TOVA include:

1. Errors of Omission, failure to respond to the designated target, are interpreted as a measure of inattention.
2. Errors of Commission, inappropriate response to the non-target stimulus, are interpreted as a measure of impulsivity or failure of inhibition.
3. Mean Correct Response Time, the average latency of correct response, is interpreted as a measure of processing and response time.
4. Standard Deviation Reaction Time, computed as the square root of the average squared deviations from the mean, is a measure of variability or consistency.
5. ADHD score, represent an average score test result.

Results on TOVA subcategories are presented as T Score. A score of over 85 is considered normal. The TOVA also

compute an average score test result, called ADHD Score. An ADHD score of –1.80 or more positive is considered normal.

Intervention

As participants in the study, all patients agreed to refrain from seeking other types of care, unless medically necessary, during the duration of the study. They also agreed not to make any changes to their lifestyle routine (exercise, nutrition, …) during the study.

All patients were seen twice a week for two months, and cared for with Network Spinal Analysis level 1. At each visit the patient was entrained as deemed necessary by the chiropractor using NSA Phasing system. All patients claimed they respected those guidelines. During the study, one patient seeked emergency medical care for a wrist sprain due to a fall. She was given a wrist splint and took anti-inflammatory medications for three days.

A first re-evaluation was done at one month (8 visits) to evaluate neurospinal progress to care. No reassessment of attention was performed at this first re-evaluation. After 2 months of care (16 visits), all patient were again re-evaluated. A TOVA was repeated at the second re-evaluation to assess for possible changes in attentional capabilities. For each patient, the pre- and post- TOVA were done at the same time of the day (in the morning)

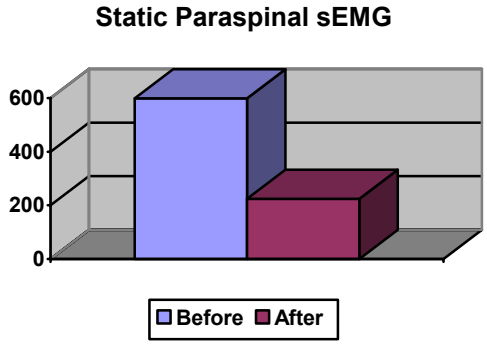
During the first two months of care, all patients experienced full development of the respiratory wave. This phenomenon, unique to NSA care, is observed as a deep, ample breath starting from the pelvis and travelling to the occipital areas. It is considered to be the expression of the breath entraining to spinal motion, and is associated with a reduction in spinal tension parameters and improved quality of life [17].

Results

Static paraspinal surface electromyography (sEMG)

Average sEMG for the nine patients before care was 599. Average sEMG score for the nine patients was 224 after care. All patients experienced reduction in the sEMG pattern of activation. Statistical analysis of individual change using non-parametric test (Mann-Whitney test) demonstrated that this change was significant (p=0.08). Before and After sEMG Changes are shown in Table 6.

Table 6



Test of Variable of Attention

As outcome measures of attention, we used five elements from the Test of Variables of Attention: ADHD score; omission errors; commission errors; reaction time; and variability.

ADHD Score / Overall TOVA

Using the ADHD score, which represents an overall measure of performance on the TOVA, all patients demonstrated significant impairment in attention on the visual portion of the TOVA. Average ADHD score for the nine patients before care was – 3.74 (range – 8.54 to – 1.89), well below normal (normal = -1.80 or more positive). All patients had at least two significant changes out of the five possible. The average number of change was 3.33 out of five (range 2 – 4). The ADHD score represented the most changes since 9 out of nine patients (100%) had a significant change. It was followed by reaction time (7 out of nine patients; 77%) and variability (6 out of nine patients; 66%).

All patients experienced significant change in ADHD score. All patients tested but one (patient 4) normalized their ADHD score after two months of care. After two month of chiropractic care, the average ADHD Score was +0.213. It is of interest that the patient who did not normalize her ADHD score (patient) was then referred to her medical doctor for complementary lab work and was subsequently diagnosed as suffering from severe hypothyroid disease.

According to TOVA interpretation, a change in ADHD Score is considered clinically significant if it reaches 0.5. The average change from – 3.74 to + 0.213 therefore represents a strong clinically significant change. Statistical analysis revealed the change to be significant (p=0.008). Individual pre and post result in ADHD Score are shown in table 7.

Errors of omission

Four patients had abnormal omission score before care. Four out of nine patients (44%) had a significant improvement in omission; but only one of the patients with abnormal omission experienced improvement. Statistical analysis demonstrated that change was not significant (p=0.173)

Errors of commission

Three patients had abnormal commission score before care. Four out of nine patients (44%) had a significant improvement in commission score; the three patients with an abnormal score normalized after two month of care. Statistical analysis demonstrated that the change was not significant. (p=0.86)

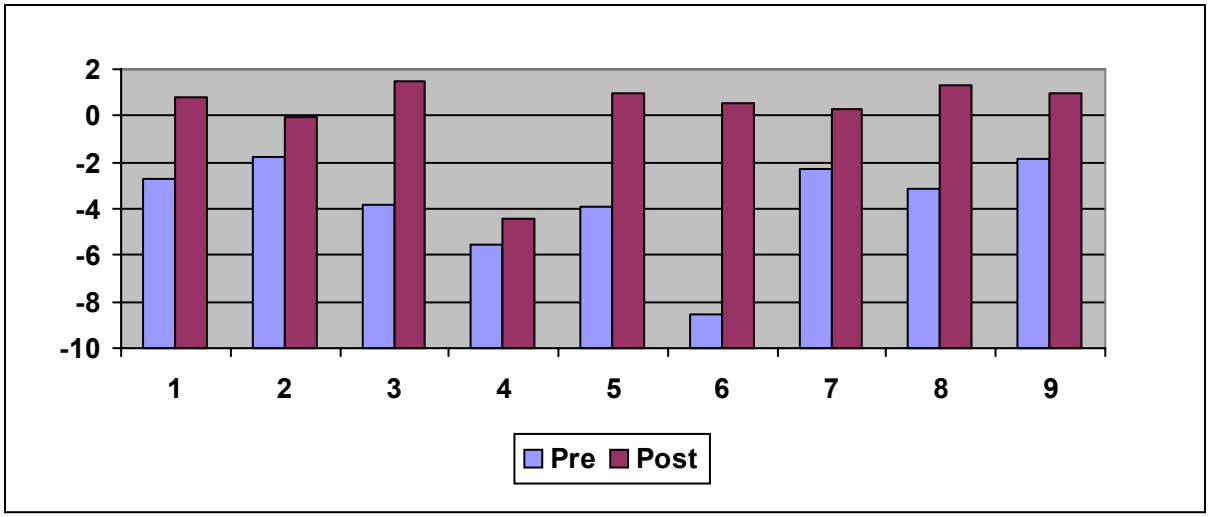
Reaction time

Two patients had abnormal reaction time before care. Seven out of nine patients (77%) had a significant improvement in reaction time; the two patients with abnormal reaction time normalized. Statistical analysis demonstrated that the change was significant (p=0.008)

Variability

Five patients had abnormal variability before care. Six patients out of nine (66%) had a significant improvement in variability; out of the five patients with abnormal variability, three normalized, one was significantly improved and the last one demonstrated no significant change. Statistical analysis demonstrated that the change was significant (p=0.035). Individual pre and post result in omission, commission, reaction time and variability are shown in table 8.

Table 7 Individual Pre and Post ADHD Scores



We were interested in knowing whether there were any correlation between the Pre sEMG score and the five variables on the Pre TOVA, as well as post sEMG score and the five variables of the Post TOVA. Statistical analysis of correlation was realized using Spearman's rho. No significant correlations were found between the various variables. We did not perform this analysis using other variables of neurospinal integrity (such as palpation of the active and passive subsystem) or neurological deficits from the neurological functional evaluation.

Discussion

Neuroanatomy of Attention

Recent advances in the neurosciences have suggested that there exist multiple attentional networks in the brain, each of which subserves a different type of attention [18]. Therefore, attention is neither the property of a single brain area nor is it a collective function of the brain working as a whole [7].

One of the most accepted and supported models of attention is the one proposed by Posner and Petersen [19]. In that model, it is proposed that the sources of attention form a specific system of anatomical areas which can be subdivided into three networks that carry out the function of *alerting*, *orienting* and *executive control* [6].

Alerting involves a change in the internal state to become ready. It is an important source of attention in the sense that maintaining an adequate level of alertness is critical for optimal performance.

Orienting involves selectively focusing on one or a few items out of many candidate inputs.

Executive control of attention is related to monitoring and resolving conflicts in the presence of competing information.

It is often required in higher cognitive operations including planning and decision-making. Neuroimaging and neuropathological studies have suggested that those three functions are carried out by specific brain regions. Those are shown in table 9.

In addition to those brain regions, recent evidence accumulated from the neuroimaging study of ADHD and other neuropsychiatric suggest that the cerebellum, most especially the vermal region of the cerebellum is involved in the neural circuitry of attention. In one study, Gottwald and colleagues demonstrated that patients with focal cerebellar lesions had clear impairment in attention and working memory, especially divided attention, ie in the executive control of attention [22]. Townsend and colleagues suggested that the cerebellum plays a role in attentional network, serving as an antecedent structure providing relatively unspecific effects on different components. In that view, the frontal cortex could only perform its attentional tasks in an optimal way if inputs from the cerebellum are unimpaired. Therefore, the cerebellum provides a mechanism predicting internal conditions necessary for a particular motor or mental operation, and then setting the corresponding conditions.[23] In their paper, Townsend and colleagues write:

"The cerebellum prepares internal conditions […] by repositioning sensory receptors; by altering cerebral blood flow levels; by enhancing neural signal to noise; by enhancing neural responsiveness in hippocampus, thalamus and superior colliculus; by modulating motor control systems." [23]

The role of the cerebellum is discussed further below under possible mechanisms of action of chiropractic care.

Possible Mechanisms of Action: Stress Hormones

Stress has been implicated clinically in the pathogenesis of mental illness. The medial prefrontal cortex has an important role in mediating responses to stressful situations. It does so by modulating the hypothalamic-pituitary-adrenal (HPA) axis [24]. Animal studies have demonstrated that stress impacts the brain by altering the morphology of prefrontal cortical dendrites [25]. One study demonstrated that those morphological changes predicted impaired attentional set-shift [26]. Research has also shown that those changes are potentially reversible.

One interesting finding by Sullivan and Gratton is that unilateral lesions of the right medial prefrontal cortex abolished the stress-induced secretion of glucocorticoids. Animals with those lesions failed to interpret sensory inputs related to stress and failed to integrate this with neuroendocrine responses [27]. This sounds very similar to a reduction in bodily sensations awareness. Network Spinal Analyis has for a long time hypothesized that patients under stress tended to suffer from reduced body awareness (also called alexysomia). One objective of NSA care is to increase body awareness of the patient. We may hypothesize that the reduced attentional ability seen in our patient is not only directed toward the external environment, but also toward the internal environment. By improving attention, NSA care may well also improve the patient's ability to pay attention to his or her internal milieu.

In one study of healthy aging adults, it was demonstrated that relaxation response training improved attention on a simple attention task [28]. The relaxation response is a mind-body intervention that counteracts the harmful effects of stress. One pilot study of NSA care suggested a decrease in electrodermal activity, a measure of sympathetic activation. It was suggested that NSA care had a "sympathetic quieting effect" [29].

Table 8. Pre and post T scores in omission, commission, reaction time and variability

Subject	Omission		Commission		Reaction time		Variabilty	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	85	**100**	96	101	102	**117**	82	**100**
2	108	108	100	98	103	110	72	**98**
3	103	108	82	**100**	87	**121**	85	**106**
4	<40	<40	108	105	86	93	47	**59**
5	78	*61*	77	**119**	96	**117**	46	**100**
6	76	76	52	**113**	66	**109**	<40	**104**
7	77	**108**	94	100	97	**110**	93	87
8	97	**107**	114	*100*	71	**111**	74	68
9	83	**108**	95	**118**	96	**110**	93	93

Black = significant positive change ; *italic* = significant negative change

This study, with many anecdotal reports from patients experiencing NSA care, may suggest that NSA triggers physiological changes similar to the relaxation response. One mechanism for improved attention may therefore be that NSA care triggers a relaxation response within patients, allowing for attenuation of negative effects of stress and potential reversal of dendritic spine losses in prefrontal cortical areas, with concomitant improvement in attention.

Table 9 : Neuroanatomy of attention (compiled from Wang [6], Fan [20] and Perry [21])

Function	Attention subcategory	Possible neural substrates
Alerting	sustained attention	Frontal and parietal regions, especially of the right hemisphere
Orienting	selective attention	Superior and inferion parietal lobe, frontal eye field, superior colliculus, and thalamus (pulvinar and reticular nuclei)
Executive control	divided attention	Midline frontal areas (anterior cingulated gyrus) and dosrsolateral prefrontal cortex

Possible Mechanisms of Action: Activation of Spino-Cerebellar Pathways

A growing number of studies suggest that attention deficit/ hyperactivity disorder (ADHD) is a disorder involving deficit in central executive functions [30]. The relationship between the cerebellum, the basal ganglia and the prefrontal regions with regards to higher cognitive functions has also been recently studied [31]. Growing evidence suggests that AHDH [32] and other neuropsychiatric disorders such as schizophrenia [33] involve a

dysfunction of a cerebello-thalamo-prefrontal neural loop. Studies have suggested that the cerebellum is not only affected in its function, but also in its size. For example, Berquin, using a morphometric MRI study, demonstrated that right-handed ADHD boys had a 8.5% reduction in volume of the vermis, the central aspect of the cerebellum [32]. Connections between the cerebellum with prefrontal associative areas has lead some researchers to suggests that the vermis may act as a "coprocessor" which enhance speed and efficiency in attention and executive functions [34]. In fact, at least one fMRI study has demonstrated increased blood flow in the vermis during a shift-attention task [35]. Moreover, it has been shown that patients with cerebellar lesions have shifting attention deficits [36].

It is notable to realize that the vermal region of the cerebellum is part of what is called the *spinocerebellum*. This structure receives its main afferent information from the head and proximal and midline structures of the body, especially the spine and postural musculature [37].

The concept of diaschisis may bring some light to the relationship between cerebellar dysfunction and prefrontal dysfunction. Diaschisis is defined as a functional depression of brain function at a structurally intact site remote from, but functionally related to, an area of brain lesion. Diaschisis is a well-recognized phenomenon in strokes. For example, crossed cerebellar diaschisis (CCD) is a matched depression of blood flow and metabolism in the cerebellar hemisphere contralateral to a focal, supratentorial lesion and is a well-recognized phenomenon following cerebral infarction. The most likely mechanism underlying CCD is the interruption of the corticopontocerebellar connections by the infarct causing deafferentation and transneural metabolic depression of the contralateral cerebellar hemisphere [38].

We propose that prefrontal dysfunction leading to altered attentional capabilities seen in our patients is related to a diaschetic mechanism involving the cerebellum, and more specifically the vermal region of the cerebellum. However, in those cases, the cerebellar dysfunction is not due to a "hard" lesion, but is itself a diaschetic consequence of dys-afferentiation from spinal structures. The latter being most likely due to vertebral subluxations or other postural imbalances, combined with other causes from improper lifestyle.

Based on the previous considerations, it may possible that the entrainment of respiration to spinal motion (called the Respiratory wave) mobilizes the entire spinal system; thereby provide a tremendous amount of activation of joint mechanoreceptors and muscle spindle. This then results in activation of spinocerebellar tracts to the vermis of the cerebellum. Such increase in afferentiation provides increased activation of neural pathways, which is known to stabilize unstable neurons.

Increased neuronal stability of the vermis may then be translated, as hypothethized by Townsend [23] (see above), in better function of prefrontal areas. Proprioceptive stimulation is known to impact brain function. For example, Muller demonstrated that pathologic cognitive processes caused by traumatic brain injury could be improved by proprioceptive stimulation [39]. Using cortical physiological mapping, Carrick demonstrated that chiropractic adjustment increased cortical activity on the side contralateral to the adjustment [40].

Possible Mechanisms of Action: Synchronization of Thalamocortical Oscillations and Temporal Binding

A specific feature of brain function is the presence of brain waves. Those waves oscillate at various frequencies, depending on the functional state of the brain. Oscillatory activity is an emerging property of the thalamocortical system [41].

In the waking state, the brain oscillates at fast rate, called gamma oscillations. Interestingly, research has shown that gamma activity is associated with attentiveness [42,43] and focused arousal [44]. It has also been proposed that synchronization in the gamma frequency range is related to cognitive processing and important for temporal binding of sensory stimuli [45].

Thalamocortical neurons (TC) possess a large set of intrinsic currents that enable them to contribute to the various oscillatory activities and/ or to mediate some of them. They display fast oscillations (around 40Hz, generally between 30-80Hz) [46]. Those fast oscillations are due to their intrinsic properties, as well as synaptic inputs. Those inputs arise mainly from ascending sensory pathways (medial lemniscus, optic tract, brachius of the inferior colliculus and brachum conjectivum) and from brainstem modulatory system; as well, they are also influenced by corticothalamic integration [41].

Of more interest for the chiropractor is that the oscillatory nature of TC neurons is also dependent on prethalamic relay stations such as the deep cerebellar nuclei, and that it has been shown that lesions of the brachium conjectivum changes the oscillatory frequency of TC neurons [46]. Of importance is the fact that Pinault demonstrated that, although oscillatory frequencies persisted after transection of, for example, the capsule, they could no more be recorded after lesions of the dorsal columns [47], leading the author to conclude that TC neurons oscillations represented mainly excitatory potentials of prethalamic origin.

Based on similar mechanisms as proposed in the previous section, we suggest that proper activation of dorsal column circuitry is essential for optimal excitation of TC neurons. Afferentiation from pre-thalamic structures, combined with the intrinsic nature of TC neurons, serve as the basis for the existence of fast (gamma) oscillation. Those gamma oscillations are necessary for proper temporal binding of sensory information, optimal cognitive processing, focused arousal and attentiveness.

On the other hand, improper afferentiation of TC neurons via dorsal colums due to vertebral subluxations or other types of postural imbalances, may result in altered oscillatory frequencies of the TC network. Combined with other environmental factors, this can result in altered neuronal functions subserving attention and other cognitive processes, especially of the right hemisphere. This leads to a potential functional dysconnection syndrome [48].

The Respiratory wave that patients develop under NSA care may serve as a self-generated, rhythmic mechanism that stabilize and restore proper TC neurons oscillations, via direct activation of dorsal column pathways and indirect activation of deep cerebellar nuclei. Improper integration of TC oscillatory loops has been termed thalamocortical dysrhythmia syndrome and has been suggested as a prominent feature of certain neuropsychiatric disorders, including ADHD [49,50]. The interested reader is directed to the excellent textbook "*Neurobehavioral disorders of childhood*" [51] by Melillo and Leisman for a more complete review of those concepts. Other alternative explanations cannot be disregarded.

Limitations of the Study

The observational nature of this case series precludes us from definitive conclusions and from drawing conclusions as to cause and effects relationship. Small sample size and lack of blinding are notable limitations of this report. Since we had no control group, nor randomisation process, we cannot exclude that alternative variables may explain our results. However, it has been shown that TOVA testing does not result in learning effect; in fact, quite the contrary is true. Therefore, we can already exclude testing learning effect as a variable in the observed improvement.

Conclusion

In this study, about 18% of patients seeking chiropractic care had attention deficit as identified by a continuous performance test. This number is definitely higher that the expected percentage of adults suffering from attention deficit in the general population (1-6%). This bias could be explained by the fact that our clinic is known to take care of individuals suffering from those types of disorders.

Our sample was small and statistical analysis failed to demonstrate any correlation between neurospinal integrity, as measured by surface electromyography, and improvement in the various parameters of attention. Further studies will need to include greater sample size and expand the conceptualization of neurospinal integrity to other parameters such as static palpation, motion palpation and other diagnostic instruments (not just sEMG), as well as neurological deficits evidenced by functional neurological evaluation to determine if any correlations do exist.

Within the limitations of the study, the clinical progress experienced by the patients suggest that two months of care with Network Spinal Analysis may positively affect the brain of adults by creating plastic changes in the prefrontal cortex and other cortical and subcortical areas serving as neural substrate for the cognitive process of attention. The observations documented in this case series provide preliminary evidence that NSA care may improve, and even normalize, attentional abilities of some adult individuals. These findings may be of importance for individuals suffering from attention deficit. Further research into this exciting area is greatly needed in the form of well designed clinical trials.

References

1. Wikipedia, the free encyclopedia: www.en.wikipedia.org
2. James W. The Principles of Psychology. Vol 1. New York: Henry Holt; 1900
3. Filley CM. The Neuroanatomy of Attention. Seminars in Speech and Language. 2002;23(2):89-98
4. Palmese CA, Raskin SA. The Rehabilitation of attention in individuals with mild traumatic brain injury, using the APT-II programme. Brain Injury, 2002;14(6):535-548
5. Geschwind N. Disorders of attention: a frontier in neuropsychology. Philos Trans R Soc Lond B. 1982;298:173-185
6. Wang H, Fan J, Johnson TR. A symbolic model of human attentional networks. Cognitive Systems Research 2004;5:119-134
7. Posner MI. Attention: the mechanisms of consciousness Proc Natl Acad Sci 1994; 91:7398-7403
8. Wender PH, Wolf LE, Wasserstein J. Adults with ADHD: an overview. Ann N Y Acad Sci 2001; 931: 1-16.
9. Goldman LS, Genel M, Bezman RJ, et al for the Council on Scientific Affairs, American Medical Association. Diagnosis and treatment of attention-deficit/hyperactivity disorders in children and adolescents. JAMA 1998;279:1100-1107.
10. Barkley RA. Taking charge of ADHD. The Guilford Press: New York 2000.
11. Giesen JM, Center DB, Leach RA. An evaluation of chiropractic manipulation as a treatment of hyperactivity in children. J Manipulative Physiol Ther. 1989; 12(5): 353-363
12. Bastecki AV, Harrison DE, Haas JW. Cervical kyphosis is a possible link to attention deficit/hyperactivity disorder. J Manipulative Physiol Ther 2004; 27(8):e14
13. Epstein DM The transition of Network Spinal Analysis Care: Hallmark of a client-centred wellness education Multi-component system of Health Care delivery. J Vertebral Subluxation Res 2004; april 5
14. Schuster TL, Dobson M, Jauregui M, Blanks RH. Wellness Lifestyles II : Modeling the dynamic of wellness, health lifestyle practices and Network Spinal Analysis. J Alt Compl Med 2004: 10(2): 357-367
15. Shin LM, Scott LR, Pitman RK. Amygdala, medial prefrontal cortex and hippocampal function PTSD. Ann N.Y. Acad Sci 2006;1071:67-79
16. Forbes, Gordon B.(1998). Clinical Utility Of the Test Of Variables Of Attention (TOVA) In the Diagnosis of Attention-Deficit/Hyperactivity Disorder. *Journal of Clinical Psychology*, Vol. 54 (4), 461-476.
17. Blanks RHI, Schuster TL, Dobson M. A retrospective assessment of Network Care using a survey of self-rated health, wellness and quality of life. J Vertebral Subluxation Res 1997;1:11-27
18. Fan J, Raz A, Posner MI. Attentional mechanisms. In: Encyclopedia of Neurological Sciences. San Diego, CA: Academic Press 2003
19. Posner MI, Petersen SE. The attention system of the

20. human brain. Annuel Review of Neuroscience 1990;13:25-42
21. Fan J, McCandliss BD, Sommer T, Raz A, Posner MI. Testing the efficiency and independence of attentional networks. J Cog Neurosci 2002;14(3):340-347
22. Perry RJ, Hodges R. Attention and executive deficits in Alzheimer's disease: a critical review. Brain 1999;122:383-404
23. Gottwald B, Mihajlovic Z, Wilde B, Mehdorn HM. Does the cerebellum contribute to specific aspects of attention? Neuropsychologia 2003;41:1452-1460
24. Townsend J, Courchesne E, Covington J et al. Spatial attention deficits in patients with acquired or developmental cerebellar abnormality. The Journal of Neuroscience 1999; :5632-5643
25. Herman JP, Cullinan WE. Neurocircuitry of stress: central control of the hypothalamo-pituitary-adrenocortical axis. Trends Neurosci 1997;20:78-84
26. Radley JJ, Rocher AB et al. Repeated stress induces dendritic spine loss in the rat medial prefrontal cortex. Cereb Cortex 2006:16:313-320
27. Liston C, Miller MM et al. Stress-induced alterations in prefrontal cortical dendritic morphology predict selective impairment in perceptual attentional set-shit. J Neurosci 2006:26:7870-7874
28. Sullivan RM, Gratton A. Lateralized effects of medial prefrontal cortex lesions on neuroendocrine and autonomic stress response in rats. J Neurosci 1999:19:2834-2840
29. Galvin JA, Benson H et al. The relaxation response: reducing stress and improving cognition in healthy aging adults. Complement Ther Clin Pract 2006;12:186-191
30. Miller E, Redmond PD. Changes in Digital Skin Temperature, Surface Electromyography, and Electrodermal Activity in Subjects Receiving Network Spinal Analysis™ Care. J Vertebral Subluxation Res 1998;2:87-95
31. Pennington BF, Ozonoff S. Executive functions and developmental psychopathology. J Child Psychol Psychiatry 1996;37:51-87
32. Middleton FA, Strick PL. Anatomical evidence for cerebellar and basal ganglia involvement in higher cognitive function. Science 1994; 266:458-461
33. Berquin PC, Giedd JN et al. Cerebellum in attention-deficit hyperactivity disorder: a morphometric MRI study. Neurology 1998:50:1087-1093
34. Andreasen NC, O'Leary DS et al. Schizophrenia and cognitive dysmetria : a positron-emission tomography study of dysfunctional prefrontal-thalamic-cerebellar circuitry. Proc Natl Acad Sci USA 1996;93:9985-9990
35. Bower JM. Control of sensory data acquisition. Int Rev Neurobiol 1997;41:489-513
36. Le TH, Hu X. Cerebellar involvement in intramodality attention shifting. Society for Neuroscience Abtracts 1996;22:1856
37. Akshoomoff NA, Courchesne E. ERP evidence for a shifting attention deficit in patients with damage to the cerebellum. J of Cogn Neurosci 1994;388-399
38. Kandel ER, Schwartz JH. Principles of Neural Science. McGraw-Hill: New York 2000, 4th edition.
39. Infeld B, Davis SM. Crossed cerebellar diaschisis and brain recovery after stroke. Stroke 1995;26:90-95
40. Muller SV, von Schweder AJ. The effects of proprioceptive stimulation on cognitive processes in patients after traumatic brain injury. Arch Phys Med Rehabil 2002;83:115-121
41. Carrick FR. Changes in brain function after manipulation of the cervical spine. J Manipulative Physiol Ther 1997;20:529-545
42. Timofeev I, Bazhenov M. Mechanisms and biological role of thalamocortical oscillations. In: Trends in Chronobiology Research. Nova Science Publishers 2005: 1-47
43. Bouyer JJ, Montaron MF et al. Fast fronto-parietal rythms during combined focused attentive behaviour and immobility in cat: cortical and thalamic localization. Electroencephalography and Clinical neurophysiology 1981; 51:244-252
44. Rougeul-Buser A, Bouyer JJ. From attentiveness to sleep. A topographical analysis of localized "synchronized" activities of the cortex of normal cat and monkey. Acta Neurobiol Exp (Warsz) 1975;35:805-819
45. Sheer DE. Focused arousal and the cognitive 40 Hz event-related potentials: differential diagnosis of Alzheimer's disease. Prog Clin Biol Res 1989;317:79-94
46. Singer W, Gray CM. Visual feature and the temporal correlation hypothesis. Ann Rev Neurosci 1995;18:555-586
47. Timofeev I, Steriade M. Fast (mainly 30-100Hz) oscillations in the cat cerebellothalamic pathway and their synchronization with cortical potentials. J of Physiol 1997;504:153-168
48. Pinault D, Deschenes M. The origin of rhythmic fast subthreshold depolarisations in thalamic relay cells of rats under urethane anesthesia Brain Res 1992;595:295-300
49. Melillo RM, Leisman G. Is autism/ADHD a functional dysconnection syndrome? Int J Neurosci, 2007 (in press)
50. Hermann CS, Demiralp T. Human EEG gamma oscillations in neuropsychiatric disorders. Clin Neurophysiol 2005;116:2719-2733
51. Jeanmonod D, Schulman J et al. Neuropsychiatric thalamocortical dysrhythmia: surgical implications. Neurosurg Clin N Am 2003;14:251-265
52. Melillo R, Leisman G. Neurobehavioral disorders of childhood. Kluwer Academic: New York 2004
53. Sieroff E, Piquard A. Attention and aging. Psychol Neuropsychiatr Vieil 2004; 2(4):257-269
54. Oken BS, Kishiyama SS et al. Attention deficit in Alzheimer's disease is not simulated by an anticholinergic/antihistaminergic drug and is distinct from deficits in healthy aging. Neurology 1994;44(4):657-662
55. McCoy M, Blanks RH et al. Inter-examiner and intra-examiner reliability of static paraspinal surface electromyography. Proceedings of the 2006 International Research and Philosophy Conference. Spartanburg, SC 2006.