Functional Neurology – An Introduction
by Nicole Oliver

Introduction
Neurology has been at the heart of the Chiropractic profession since its very beginning. But it is only in recent years that advances in clinical neuroscience have allowed us to understand how our treatments affect the nervous system; and how this effect can help us to restore and preserve good structure and function within the musculoskeletal system.

Chiropractors excel in their ability to detect subtle differences in musculoskeletal structure and function, for example through muscle testing, feeling for joint restrictions and checking for leg length discrepancies. These same skills can be applied to neurological testing in order to detect functional imbalances within the nervous system. Such functional neurological imbalances may be treated using traditional chiropractic techniques, various other sensory stimuli, as well as specific physical or cognitive exercises. Functional neurology is not a technique system. Rather, it advocates an open systems approach to treatment with the objective of restoring, improving and preserving the functionality of the patient’s nervous system.

Activating the central nervous system
Over recent years notions have emerged within the literature that the clinical benefit associated with manual therapy is not simply related to local segmental responses. Instead, a major therapeutic role is attributed to activation of the central nervous system (CNS) [1,2].

All manual treatment procedures stimulate mechanoreceptors, whose afferents have the potential to activate central neuronal pools. Appropriate activation of mechanoreceptive afferents can elicit therapeutically favourable motor consequences and pain modulatory effects both at spinal cord level and through descending pathways from the cerebral cortex and brainstem.

The frequency at which the CNS is activated through manual therapy depends on the intensity of the stimulus. For example, high-velocity-low-amplitude spinal manipulation (HVLA-SM) is likely to produce greater central activation than SOT blocking or mobilisation procedures, due to greater speed of tissue loading [3]. HVLA-SM is also likely to produce greater central activation than McTimoney toggle-torque-recoil adjusting or Activator instrument adjusting, because it generates a much higher peak force [3,4,5].

HVLA-SM is thought to activate high-threshold facet joint capsule mechanoreceptors that are not fired by normal physiological joint movement, thus providing a novel stimulus [6]. This reduces the likelihood of habituation and raises the probability of creating neuroplasticity. Since muscle spindles are more abundant in axial muscles [7], spinal manipulation is likely to produce greater central activation than extremity manipulation. The highest density of muscle spindles can be found in the suboccipital musculature [7]. Therefore it is probable that upper cervical HVLA-SM produces the greatest degree of central afferentation by a single intervention in common chiropractic practice.

Clinically utilising the concepts of spatial and temporal summation can further increase the activation of central neuronal pools. Rapidly performing several therapeutic interventions that utilise the same afferent pathway in sequence creates temporal summation (figure 1a), e.g. adjusting several spinal levels into the same direction in rapid succession. Simultaneously activating two or more pathways that
share a common central neuronal target creates spatial summation (figure 1b), e.g. manipulating the spine while the patient performs a visual saccade.

**Figure 1. Spatial and temporal summation**

<table>
<thead>
<tr>
<th>1a. Temporal summation</th>
<th>1b. Spatial summation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Temporal summation" /></td>
<td><img src="image" alt="Spatial summation" /></td>
</tr>
</tbody>
</table>

**The adjustment is not always good**
Achieving the greatest amount of central activation, however, is not always desirable, as it can exceed neuronal metabolic capacity and lead to neuronal cell death [8]. A successful therapeutic intervention will fire an appropriate pathway at an appropriate frequency for the individual patient. An intervention, on the other hand, that is not successful could a) fail to achieve sufficient afferent stimulation to produce favourable neuroplasticity, b) exceed neuronal metabolic capacity, or c) further increase the neuronal imbalance that is contributing to the patient’s presenting complaint.

**Equifinality inspires diversity**
Equifinality is the principle that in open systems a given end state can be reached by many potential means. Chiropractic patients can conceivably be deemed open systems, which means that different chiropractors performing different treatment interventions could all achieve the same end result, e.g. the resolution of neuromusculoskeletal dysfunction, in any given patient.

Different chiropractic techniques are likely to produce different frequencies of activation within a patient’s nervous system. Which interventions work well will depend on the individual patient’s neurological and metabolic make-up. Some chiropractic interventions will create neuroplasticity more rapidly than others. Other chiropractic modalities may exceed the patient’s metabolic capacity or further increase the neurological imbalance, and therefore not work at all or make the patient worse. It is highly likely, however, that there is more than one way to effectively treat the patient. An all-encompassing best technique does simply not exist. An understanding of functional neurology and the concept of equifinality should help us to finally put the ‘my technique is better than your technique’ argument to rest and celebrate the diversity within our profession.

**Central neuronal targets of manual therapy**
Manual therapy has been associated with activation of mechanoreceptors, including muscle spindles, Golgi tendon organs and joint mechanoreceptors [6,9]. Their afferents transmit proprioceptive information to the CNS, with muscle spindles providing the largest contribution [10]. Spindle afferents
project via spinocerebellar tracts to the ipsilateral cerebellum for unconscious proprioception and via nucleus Z or the cuneate nucleus and then via the thalamus to the contralateral cortex for conscious proprioception [10,11]. Activation of the ipsilateral cerebellum is likely to produce further excitation in the contralateral cortex.

Figure 2 summarises the likely pattern of CNS activation through manual therapy. Adjusting the left extremity or adjusting the cervical spine into left lateral flexion coupled with left rotation probably activates the left cerebellum and right cortex. This is substantiated by the finding that passive mobilisation of the elbow and knee predominantly stimulates the contralateral sensorimotor cortex [12].

**Segmental neurological effects of high-velocity-low-amplitude cervical spinal manipulation**

Coupled manipulation of the cervical spine into right lateral flexion/right rotation is likely to rapidly stretch the paraspinal and spinal intrinsic muscles that resist this movement and compress the muscles that facilitate this movement. Manipulative-like loads in cats have been shown to stimulate both Golgi tendon organs and muscle spindles predominantly during the manipulative impulse [9].

The Golgi tendon reflex operates as a protective feedback mechanism to control the tension of a muscle by causing relaxation before the tendon tension becomes high enough to cause damage. Rapid stretching of in this case the left paraspinal muscles and spinal intrinsic muscles that resist right lateral flexion/ right rotation is therefore likely to stimulate their Golgi tendon organs, which causes a reflex reduction in the tone of these muscles.

Compression of skin and muscles on the right side of the neck by the contact hand presumably stimulates muscle spindles as well as various skin mechanoreceptors, leading to a reflexive increase in muscle tone [13]. Figure 3 summarises the spinal reflex mechanisms that could alter local muscle tone in response to coupled cervical spinal manipulation.
Common axis of central neuronal dysfunction
Loss of function and electrical activity in one brain region is likely to produce secondary reduction in function and electrical activity in areas remote from the lesion but neuronally connected to it; this is referred to as diachisis. The most common forms of diastasis observed in humans are crossed corticocerebellar and crossed cerebellocortical [14,15]. Corticoreticular diastasis can also occur. Corticoreticular inputs into the mesencephalon are predominantly ipsilateral [16]; corticoreticular projections to pontomedullary regions are bilateral, but the majority (62%) arise from the ipsilateral cortex [17]. Clinically, this frequently manifests in a functional disconnect involving the cortex, ipsilateral brainstem and contralateral cerebellum.

Knowing where to adjust, when not to adjust and what to do when adjusting is not enough
The brain powerfully influences muscle tone, posture and pain processing, and chiropractic treatment purportedly influences brain function [1,2,18,19]. Since alterations in muscle tone, posture and pain processing form the underlying basis for the majority of conditions successfully treated by chiropractors, it could be argued that chiropractors often (unknowingly) treat brain dysfunction. It stands to reason that if chiropractors were able to assess for functional imbalances within the CNS, understood the likely central and segmental neurological effects of their treatment interventions and could employ a means of post-testing to determine whether their chosen treatment modalities were neurologically appropriate for the individual patient, they would be able to treat brain dysfunction more purposely and with greater specificity.

For any musculoskeletal disorder in which brain dysfunction is the underlying cause or a perpetuating factor, specifically treating the brain dysfunction in addition to any segmental joint and muscle abnormalities would conceivably maximise the potential treatment response and help to prevent early relapse. Understanding and treating according to the patient’s central neurological dysfunction may also help to minimise undesirable side effects of treatment, such as soreness, headache or dizziness; these could be the result of exceeding the patient’s neuronal metabolic capacity or worsening the functional imbalance within their CNS.

There are situations in which dysfunction in the nervous system will not respond well to any sort of spinal manipulation or soft tissue therapy, because the afferent pathways stimulated by manual therapy do not activate the dysfunctional brain region sufficiently to produce lasting changes, i.e. neuroplasticity. One such brain region is the vestibulocerebellum (floculonodular lobe) and its associated vestibular connections. Unilateral vestibular dysfunction is frequently associated with an ipsilateral head tilt, due to deviation of the subjective vertical [20,21], and with reduced vestibulospinal activation of the ipsilateral erector spinae muscles [22]. Spinal pain syndromes that develop as a consequence of vestibular-induced postural or muscle imbalances are unlikely to respond to adjusting alone; they will usually require vestibular rehabilitation to achieve more complete recovery [23].

Some patients compensate for vestibular dysfunction by stiffening their spine, probably because they cannot rely on vestibular inputs for postural control [24]. Spinal adjusting to reduce stiffness can disrupt their compensation mechanism, frequently producing greater post-treatment pain and sensations of disequilibrium, vertigo or dizziness.

Mens sana pro corpore sano - why brain balance is important for musculoskeletal balance
Muscle imbalances are frequently associated with musculoskeletal pain [25,26]. They can be caused by
unbalanced activity or repetitive strain, but they can also be caused by imbalances within the extrapyramidal motor system. The descending spinal projections of the extrapyramidal motor system are the reticulospinal, rubrospinal, tectospinal and vestibulospinal tracts. We will consider vestibulospinal and pontomedullary reticulospinal influences on muscle tone and posture.

Figure 4 depicts the rostral and caudal projections of the vestibular nuclei. The lateral vestibulospinal tract arises from the lateral vestibular nucleus. It has excitatory effects on both alpha and gamma motor neurons of ipsilateral trunk and limb extensors [27]. Vestibulospinal fibres act primarily on motor neurons in medial parts of the ventral horn, which innervate axial and proximal limb muscles [28]. Hypofunction in this pathway may clinically result in an ipsilateral head tilt and/or head rotation, weak ipsilateral spinal extensors, and internal rotation of the ipsilateral shoulder and hip.

The medial vestibulospinal tract arises from the medial vestibular nucleus. It forms the descending component of the medial longitudinal fasciculus (MLF) and projects bilaterally to cervical and upper thoracic spinal intrinsic muscles. It functions to stabilise the head in relation to the body during movement [29]. The ascending component of the MLF arises from the superior and medial vestibular nuclei and projects to the extraocular muscles. Through the vestibuloocular reflex (VOR) it facilitates the stabilisation of visual images on the retina during movements of the head.

Within the MLF there are neurons that have oculomotor projections and neurons that have spinal projections. But there are also neurons that project both to the extraocular motor nuclei and to the spinal cord [30]; these are likely to coordinate movements of the head and eyes [29]. Clinically this suggests that cervical and upper thoracic spinal intrinsic muscle dysfunction is frequently associated with VOR impairment. VOR impairment is also frequently accompanied by deficient pursuit eye movements and a deficient slow phase of the optokinetic nystagmus [31]. Examining eye movements may therefore be a valuable clinical indicator of spinal intrinsic muscle function.

Another important system for the control of muscle tone and posture is the pontomedullary reticular formation (PMRF). The corticoreticulospinal pathway is thought to play an important role in ensuring that postural responses are scaled appropriately to the voluntary movements that they accompany [32].
The net output of the PMRF is to release the ipsilateral limb from its antigravity role and assist reaching movements; it also contributes to stabilising posture to ensure that the reach can be made [33,34]. In humans, the antigravity muscles are considered to be the extensors of the lower limb and the flexors of the upper limb [35,36].

The crossed pattern of muscle facilitation by the PMRF is illustrated in figure 5. Increased output of the right PMRF is likely to increase tone in the right upper limb extensors, right lower limb flexors, left upper limb flexors and left lower limb extensors, relative to the respective antagonist muscles. This pattern most likely extends into the spinal muscles, whereby the cervical and upper thoracic paraspinals are functionally related to the ipsilateral upper limb extensor muscles and the paraspinals below mid thoracic level are related to the ipsilateral lower limb extensors. Therefore, a functional reduction in PMRF output is clinically likely to manifest in a reduction of strength and tone in all ipsilateral extensors above and flexors below mid thoracic level. Due to such muscle imbalances and consequent alterations in joint angulation, a patient with reduced activity in his right PMRF may be more susceptible to conditions such as right rotator cuff impingement, right lateral epicondylitis, entrapment neuropathies of the right median and ulnar nerve, right thoracic outlet syndrome, left medial epicondylitis, left radial neuropathy, left iliobial-band syndrome, left trochanteric bursitis and left hip osteoarthritis.

**Brain modulation of pain**

Appropriate modulation of nociceptive afferent activity is heavily dependant on the functional integrity of cortical and brainstem regions [37]. It has been shown that stimulation of the frontal lobe (motor cortex) has an antinociceptive effect, thought to be due to inhibition of thalamic sensory neurons and disinhibition of neurons in the periaqueductal gray [38]. Antinociceptive effects have also resulted from stimulation of the periaqueductal gray (mesencephalon), nucleus raphe magnus (medulla) and locus coeruleus (pons) [39,40,41]. It would thus seem prudent for chiropractors to assess for and treat any cortical and brainstem dysfunction, as such dysfunction could impair proper pain modulation at both thalamic and spinal cord level.

**Conclusion**

Chiropractic treatment effects are probably mediated by the nervous system. Neuronal dysfunction can cause and be caused by musculoskeletal dysfunction. Functional imbalances within the nervous system are likely to create abnormalities in muscle tone, posture and pain processing. Assessing the pretreatment state of a patient’s nervous system and being able to monitor the neuronal effects of treatment modalities may help to achieve better therapeutic outcomes whilst minimising undesirable side effects. Functional neurology is the clinical application of academic neuroscience. The literature clearly documents the afferent pathways activated by sensory stimulation, the efferent pathways that can alter muscle tone and posture, the various intercerebral connections and the functional roles of individual brain regions. Further studies, however, are needed to directly verify the neurological consequences of chiropractic and other therapeutic modalities, and to substantiate the overall efficacy of functional neurology.
References
34. Schepens B and Drew T (2006). Descending signals from the pontomedullary reticular formation are bilateral, asymmetric, and gated during reaching movements in the cat. Journal of Neurophysiology 96(5), 2229-2252.