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Masterclass

A pain neuromatrix approach to patients with chronic pain

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SUMMARY. **This paper presents an approach to rehabilitation of pain patients. The fundamental principles of the approach are (i) pain is an output of the brain that is produced whenever the brain concludes that body tissue is in danger and action is required, and (ii) pain is a multisystem output that is produced when an individual-specific cortical pain neuromatrix is activated. When pain becomes chronic, the efficacy of the pain neuromatrix is strengthened via nociceptive and non-nociceptive mechanisms, which means that less input, both nociceptive and non-nociceptive, is required to produce pain. The clinical approach focuses on decreasing all inputs that imply that body tissue is in danger and then on activating components of the pain neuromatrix without activating its output. Rehabilitation progresses to increase exposure to threatening input across sensory and non-sensory domains.**

INTRODUCTION

Pain and movement are the primary currencies in manual therapy. Most patients present for therapy because they are in pain and most therapies incorporate movement into assessment, diagnosis, aetiology and management. Indeed, many therapies attempt to restore movement in the hope that pain will automatically get better as movement improves. However, from aetiologic and therapeutic perspectives, it is difficult to determine the chicken and the egg: is pain caused by abnormal movement or is abnormal movement caused by pain? The current paper presents a model for management in which pain and changes in motor control are considered two dimensions of a multidimensional output of the 'pain neuromatrix'. The model is based on the author's interpretation of the current thought across the pain sciences. The theoretical background for this model is presented and the implications for assessment and intervention are discussed.

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It is important to note that there are assumptions underlying the present approach that have not yet been validated and this paper is occasionally speculative for the sake of clinical relevance. There are no illusions that one approach provides the panacea for persistent pain. Rather, it is hoped that the astute reader will take from this work those aspects that can be integrated with their clinical experience and approach in order to promote better outcomes in a population for which success is elusive.

BACKGROUND

A fundamental principle of this approach is that pain is produced by the brain when it perceives that danger to body tissue exists and that action is required. All dimensions of pain serve to promote this objective. Thus pain is a multiple system output, not just 'an unpleasant sensory and emotional experience associated with actual or potential damage...' (Merskey & Bogduk 1994). The principle that pain is primarily aimed at action is not novel — it was proposed by Patrick Wall a decade ago (Wall 1994) — however, it is yet to gain widespread acceptance. This is somewhat surprising because the notion that pain is a reliable informant of what is actually happening in the tissues is no longer tenable. There

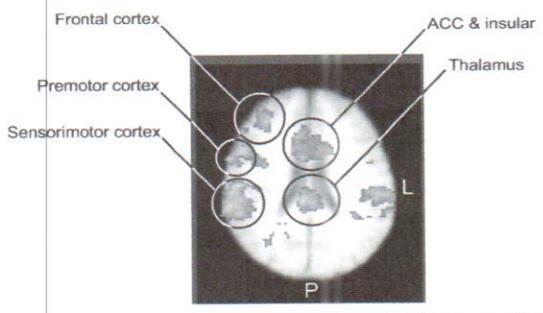

Fig. 1—Functional magnetic resonance image (axial view, multiple slices) of brain activity during painful thermal stimulation (57°C) of the left hand. Components of the pain matrix are circled — thalamus, anterior cingulate cortex (ACC), insular, frontal, premotor and primary sensory and motor cortices. Note that the image is left-right inverted such that L marks the left cortical hemisphere. P denotes posterior.

matrix is not important. Rather, the above studies suggest cortical regions that are likely to be involved in what is ultimately an individual-specific pain neuromatrix.

The virtual body

A critical component of the current approach is that pain is experienced in the body image that is held by the brain, labelled here the 'virtual body'. Although this notion seems at first glance to be counter-intuitive, this is only because the virtual body is so effective — the phantom experiences of an amputated limb is a profound case in point. Phantom experience has been discussed at length by Melzack (Melzack 1989; 1990; 1996; Melzack et al. 1997). Neuroanatomically, the primary somatosensory homunculus is the most well-known spatial representation of the internal and external physical environment (Deiber et al. 1991; Grafton et al. 1992; Grafton et al. 1996), but there are other representations as well. The dorsal insular cortex is proposed to contain representation of the *physiological condition* of the entire body (Craig 2002). This proposal is based firstly on studies that show activity of the dorsal insular during homeostatic mechanisms (including pain), and secondly on studies that show its connection almost exclusively with small-diameter afferents. It is noteworthy in this regard that small diameter afferents, although conventionally called nociceptors, are more accurately considered *interoceptors* — they detect changes in the body tissue[1] (MacIver & Tanelian 1992; Carlton et al. 2001; Cook & McCleskey 2002).

Different virtual bodies may dominate experience at different times. For example, Andre et al. (2001) demonstrated temporary non-painful and movable phantom limbs in amputees after vestibular caloric stimulation (inserting 20°C water into one ear), regardless of whether, prior to stimulation, they had no phantom, a painful phantom or a dysmorphic phantom. Those authors concluded that sudden vestibular stimulation activated a stable and intact virtual limb in order to provide the postural frame of reference on which to base a postural response to the perturbation. That is, caloric stimulation caused the virtual body to be overridden by a relatively permanent counterpart. However, in the current discussion, the incumbent virtual body is important for the very reason that it is continually updated by sensory input. Therefore, it may be an important part of the pain neuromatrix because it provides a neural substrate for allocating pain an anatomical reference. In light of this, treatment aimed at reducing pain is aimed at the virtual body, albeit commonly (but not exclusively) accessed through the corresponding body tissues.

The virtual body is also indispensable for the maintenance of coherent motor commands, including the coordination of postural and movement responses. The central nervous system (CNS) produces motor commands on the basis of (i) the predicted requirements of the movement including the predicted disturbance to stability, and (ii) the perceived current position, movement and stability of the body, such that postural control commands are effected prior to movement (Belen'kii et al. 1967; Bouisset & Zattara 1987). Thus, the virtual body provides a common platform from which experiential and motoric dimensions of pain can be launched, which make it an important consideration for clinicians interested in pain and movement.

Added complexity of chronic pain — effects on activity of the pain neuromatrix

Two inter-dependent mechanisms can contribute to chronicity — nociceptive (including humoral or immune-related dysfunction that stimulates nociceptive structures and body tissues) and non-nociceptive (cognitive–evaluative) mechanisms. In either case, there is an increase in the conviction of the CNS that body tissue is in danger and, therefore, there is an increase in activity of the pain neuromatrix.

When pain persists, both the nociceptive system and the virtual body undergo profound changes, which increase sensitivity to noxious as well as non-noxious input and corrupt the integrity of motor output. Review of the changes that occur is beyond the scope of this paper; however, potent changes occur peripherally and centrally. Alterations of wide dynamic range second-order nociceptors are particularly relevant (Doubell et al. 1999; Mannion & Woolf 2000) because these second-order nociceptors

[1] An excellent example of the distinction between nociceptors and interoceptors was described by Vallbo et al. 1999 when they observed that C fibres are exquisitely sensitive to slow, weak mechanical stimuli that evoke sensual touch.

Table 1. Material presented in education about pain physiology

The neuron	Modality-specific receptors, axon, terminal bouton
The action potential (message)	All or nothing, post-synaptic membrane potential, propogation, dromic and antidromic flow
The synapse	Neurotransmitters, inhibitory and facilitatory input, chemically driven ion channels, ion channel synthesis and absorption
Primary nociceptors (danger receptors)	Respond to danger
Second order nociceptors (danger messenger nerves)	Sum of inhibitory and facilitatory input, interneurons from non-nociceptive fibres (normally inhibitory), project to many parts of the brain
Brain output dependent on total perception of danger	All information that is relevant to that decision is considered — thoughts, memories, beliefs, explanatory model, consequences
Descending input	Inhibitory and facilitatory — also dependent on above
Primary nociceptor state-dependent functioning	Potentiation and summation, ectopic pacemakers, dorsal root ganglion, neurogenic inflammation, allodynia and hyperalgesia
Second order nociceptor state-dependent functioning	Potentiation, active blocking of ion channels, increased receptor synthesis, sprouting, activation by endocrine mediators

initial episode, reduces chronic *disability*, although the effect on chronic *pain* is not known (Symonds et al. 1995; Burton et al. 1999). There are limited data that support the efficacy of such education with patients who already have chronic pain. Anecdotally, this may be because the response that is encouraged in such programs is counterintuitive for patients because their understanding of pain is based on a structural-pathology model (i.e. that pain is analogous to injury). Pain physiology education targets this limitation by aiming to reconceptualize the underlying physiological problem of a patient's pain, on the assumption that an appropriate cognitive and behavioural/motor response will follow. This is sensible according to principles of 'deep learning', in which information is retained and understood and applied to problems at hand (Sandberg & Barnard 1997). In contrast, 'superficial' or 'surface' learning is that in which information is remembered but not understood or integrated with attitudes and beliefs (Evans & Honour 1997). To this effect, it is important to note that deep learning is facilitated when the learner is motivated (Sankaran 2001) and when the information presented is made personally relevant (Moreno & Mayer 2000), both of which are promoted by the method of education used here.

It is critical that patients understand the material that is presented — care should be taken to use various graphics (including whiteboards, hand-drawn pictures, personalized manuals), and accessible metaphors in order to achieve this objective. Education can be time consuming but we have demonstrated an effect, albeit smaller, with group programs (Moseley 2003b).

Targeting the explanatory model

Based on the underlying principle of the current work, the way that a patient explains their pain ('explanatory model') is an important consideration in targeting education and planning therapy. What story does the patient tell about their pain? Evaluation of the explanatory model is possible through direct questioning — 'What in your body do you think is causing your pain?' Most commonly, the explanatory model held by a patient is based on a structural-pathology model because that is the dominant model in the medical and lay arenas. However, the structural-pathology model is often not appropriate. Focus on a structural label for pain may actually heighten attention on the pain, emphasize the vulnerability of the body to damage and increase patients' health care consumption (Jones et al. 1988; Nachemson 1992; Hirsch & Liebert, 1998).

There are three key points to consider in modification of the explanatory model. First, care should be taken to present currently accurate information rather than an explanation that has been diluted for the sake of simplicity, to save time or to avoid a confrontation with the patient. This means that on the basis of the information that they have been presented, the patient should be unable to support an inappropriate or indefensible explanatory model. Second, the information presented should offer the patient an alternative explanatory model that is supported by the currently accurate information about human physiology. Third, the information must be presented in a manner that is respectful of the patient and acknowledges their suffering. At first glance this seems a moot point. However, the negative stigma associated with chronic pain is remarkably pervasive despite the fact that the basis of the stigma is naïve.

In summary, to be effective with education, the therapist must (i) be an expert and be perceived as such by the patient, and (ii) be respectful and compassionate and be perceived as such by the patient.

2. Activation of components of the individual's pain neuromatrix

Management framework

The following framework for management is presented to patients (Fig. 2). It represents a practical response to the pain physiology education and

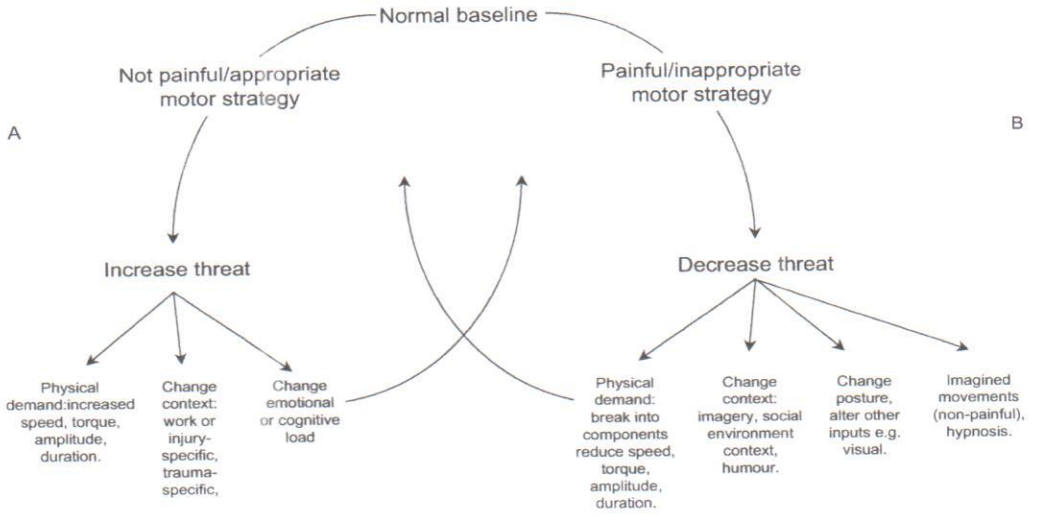

Fig. 3—Options for determining the baseline and planning progression. (A) If the normal baseline level is performed pain-free (functional task) or using an appropriate motor strategy (motor task), then the aim is to increase threat via physical, contextual changes or emotional/cognitive load. (B) If the normal baseline level elicits pain (functional task) or an inappropriate motor strategy (motor task), then the aim is to decrease threat, via similar means.

of poor performance (e.g. 'someone of your ability should have no problem performing this'), or perform the same movement from a different postural reference or within a different emotional context.

For example, a patient with chronic back pain is able to perform a near perfect voluntary abdominal muscle task in standing. Assessment of muscle activity while this patient imagines bending forward to pick up a box might reveal a loss of quality of contraction, for example marked activation of the superficial abdominal muscles/long back extensors. This finding implies that forward bending is a threatening movement and identifies success at this task as a suitable short-term goal. Threatening stimuli can be work-specific (e.g. work environment), context-specific (e.g. sitting in car) and posture-specific (that is, the postural frame of reference from which a movement is occurring).

For many patients, the changes in nociceptive and cognitive–evaluative inputs are such that the baseline is difficult to find because conventional baselines are painful (i.e. they activate the pain neuromatrix). In this situation, the aim is to utilize as much of the pain neuromatrix as possible without activating it. That is, to reduce the threat associated with the task (Fig. 3b). This may involve breaking the movement down, performing imaginary movements (that are imagined pain-free), or changing the postural reference or context of the movement. Can the task be modified in order to make it non-threatening? How can components of the movement/task be performed in a manner that does not activate the pain neuromatrix? For example, if minimal cervical rotation in sitting is painful, try cervical rotation in standing, imagined cervical rotation in sitting, performing the movement in the dark (i.e. removing visual stimuli that may add to the threat), or try imagery in which the patient is turning their head toward a cool breeze on a hot day (see Table 2). These strategies activate motor mechanisms that would normally activate the pain neuromatrix but do so in a manner that is explicitly non-threatening and therefore less likely to activate the pain neuromatrix.

Functional baselines

Functional baselines are effectively determined by the patient, however persistent assistance from the therapist is required. The functional baseline is determined by the flare-up line presented in Fig. 2, which is the point at which the patient notices a marked increase in pain that persists for more than a few minutes. Patients invariably relate to the term flare-up and recognize it as a period of severe pain which is often accompanied by incapacity, inability to sleep, nausea and vomiting, and 'drastic' treatment options. Flare-ups need not be this severe and, anecdotally at least, are less severe if the patient has gained an accurate understanding of human physiology as it relates to his/her pain. However, the prevalence of this idea of a flare-up probably reflects in part that patients find it difficult to determine their own flare-up line. Physiologically, the flare-up line may coincide with activation of tissue-initiated nociception, although there are no data that evaluate this possibility.

Persistent and skilled questioning should suffice to identify the baseline of any functional task. For

invaluable in preventing this scenario and are easy to use. In the previous example, by setting the alarm to 14 min the patient is able to benefit from distraction by reading but not exceed the training load.

Progression of motor tasks

Each time a new baseline is established, progression should involve exposure to more threatening inputs in a multidimensional manner. If the increment of progression according to physical demand is too large, it is possible to progress in other dimensions, for example, perform the motor task under stressful conditions, in more threatening emotional states, or while performing a cognitive task. Table 2 provides examples of multidimensional increases in threat associated with rehabilitation of the patient with cervical spine pain. This strategy is consistent with the theoretical goal of activating components of the neural network without triggering it to produce pain.

Progression of work

Often the success of a return to work trial is prevented by the patient exceeding a suitable training load, usually because the increment in physical load is too large. We have had greater success in the chronic pain patient group by pursuing more conservative training loads that are increased more often and with smaller increments. For example, M was a patient who presented with 4 year history of debilitating arm pain initiated and aggravated by keyboard work. She had failed two previous attempts to return to work that began with three 4 hour(h) shifts (12 h) per week. On both occasions she did not complete 2 weeks of work. In our revised progression M began with 15 min at work and incremented initially daily in 5 min blocks. Importantly, she went to work everyday. She successfully graduated to five 3-h shifts (15 h) per week by the 12th week of the program and proceeded to full time work duties in ~6 months. At first glance, this seems like a laborious return to work program. However, it was both quicker and cheaper (in terms of time off work) than previous attempts.

SUMMARY AND CONCLUSION

The current paper has presented the background, guiding principles and clinical approach to treating chronic pain using a pain neuromatrix approach. The approach is founded on key principles — that pain is a multiple system output that is activated by an individual-specific pain neuromatrix; that the pain neuromatrix is activated whenever the brain concludes that body tissue is in danger and action is required; and that pain is allocated an anatomical reference in the virtual body, upon which coherent motor output is also dependent. When pain persists, there is (i) an increase and diversification of threatening inputs such that the pain neuromatrix can be activated by all manner of threatening stimuli, nociceptive (including immune and endocrine-driven mechanisms) and cognitive–evaluative, and (ii) alterations in the morphology and behaviour of the virtual body, thus further altering motor output.

The therapeutic aspects of the approach focus on reducing the sensitivity and activity of the pain neuromatrix, via reduction of threat. The key components are education about human physiology and a systematic approach to identification and progression of motoric and functional baselines across sensory and non-sensory domains.

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