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A clinical perspective on a pain neuroscience education approach to manual therapy

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ABSTRACT
In recent years, there has been an increased interest in pain neuroscience education (PNE) in physical therapy. There is growing evidence for the efficacy of PNE to decrease pain, disability, fear-avoidance, pain catastrophization, limited movement, and health care utilization in people struggling with pain. PNE teaches people in pain more about the biology and physiology of their pain experience including processes such as central sensitization, peripheral sensitization, allodynia, inhibition, facilitation, neuroplasticity and more. PNE's neurobiological model often finds itself at odds with traditional biomedical models used in physical therapy. Traditional biomedical models, focusing on anatomy, pathoanatomy, and biomechanics have been shown to have limited efficacy in helping people understand their pain, especially chronic pain, and may in fact even increase a person's pain experience by increasing fear-avoidance and pain catastrophization. An area of physical therapy where the biomedical model is used a lot is manual therapy. This contrast between PNE and manual therapy has seemingly polarized followers from each approach to see PNE as a 'hands-off' approach even having clinicians categorize patients as either in need of receiving PNE (with no hands-on), or hands-on with no PNE. In this paper, we explore the notion of PNE and manual therapy co-existing. PNE research has shown to have immediate effects of various clinical signs and symptoms associated with central sensitization. Using a model of sensitization (innocuous, noxious, and allodynia), we argue that PNE can be used in a manual therapy model, especially treating someone where the nervous system has become increasingly hypervigilant.

Level of Evidence: VII

KEYWORDS
Pain; neuroscience; education; manual therapy

Introduction

It is currently estimated that 126.1 million adults in the US experience some pain over a 3 month reporting period, while 25.3 million adults in the US are suffering from daily chronic pain [1,2]. Chronic pain is not confined to the US, as rates of chronic pain show similar data globally [3,4]. Given the immense burden of chronic pain, it is argued that a large-scale collaborative approach is needed combining governments, third-party payers, and society as well as the medical community [3–5].

Often lost in the midst of these overwhelming numbers, is the individual suffering of the patient as well as challenges faced by the clinician treating the patient suffering from chronic pain [6,7]. Chronic pain is extremely challenging to treat. Various studies have shown clinicians struggle to treat people with chronic pain [8,9]. In the last 25 years, however, our knowledge of pain has increased considerably with advances in neuroimaging, immunology, pain neuroscience, psychosocial issues pertaining to pain, etc. [6,7]. With these advances in the knowledge of pain, and incorporation of pain neuroscience into entry-level health professions curricula, it is hoped that knowledge translation may lessen the burden on health care providers [8,9]. In physical therapy, for example, it has been shown that teaching students about the neuroscience of pain can improve their knowledge of pain [9], and lead to healthier and more positive attitudes and beliefs regarding chronic pain [8]. The increased knowledge of pain, however, may have created an unforeseen additional burden for physical therapists utilizing manual therapy [7,10]. One specific emerging pain science approach that has created a potential clinical challenge for the manual therapist has been pain neuroscience education (PNE) [11,12].

PNE is an educational strategy used by clinicians that focuses on teaching people in pain more about the neurobiological and neurophysiological processes involved in their pain experience, especially chronic pain [13–15]. Current best-evidence for musculoskeletal disorders provides growing support for PNE to positively influence

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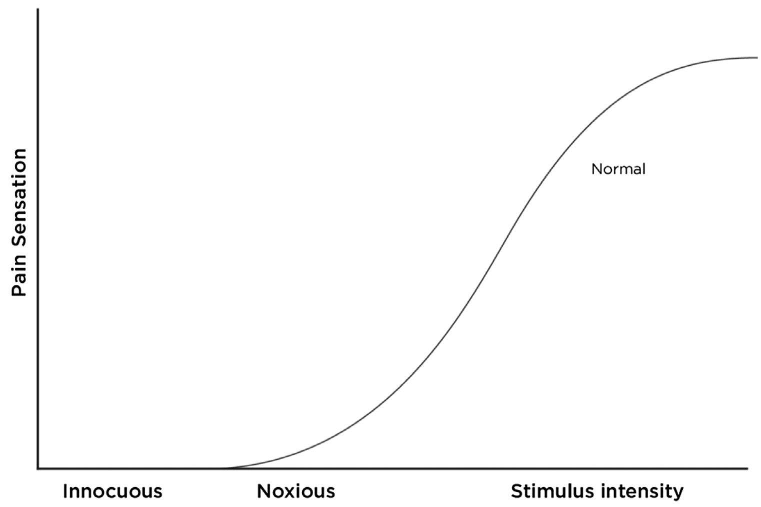

Figure 1. Pain sensation and stimulus intensity in a normal, control state.
Note: As the intensity of a given stimulus increases from innocuous to noxious, pain sensation increases in a predictable manner.

pain ratings, disability, fear-avoidance behaviors, pain catastrophization, and limitations in movement, pain knowledge, and health care utilization [15,16]. To date, PNE has been shown to be effective in various challenging conditions physical therapists face, including chronic low back pain [13], fibromyalgia [17], chronic fatigue syndrome [14], chronic whiplash-associated disorders [18], and lumbar surgery [19]. From this vantage point, PNE can thus be seen as an added clinical tool in helping clinicians with the challenge of treating chronic pain [5,7,20]. On the flipside, however, PNE may have created an added challenge for manual therapists wanting to utilize PNE. PNE focuses less on anatomical and pathoanatomical models and is often seen as 'hands-off' [11,21], while traditional manual therapy approaches often focus on biomechanical and pathoanatomical models and less on the cognitive aspects of a person's pain experience.

PNE, by its definition, is an educational intervention aiming to alter a patient's beliefs and cognitions regarding their pain experience [13,20,22]. This reeducation of pain, however, is clinically intertwined with de-education. Prior to teaching patients about the neurobiology and neurophysiology of their pain experience, various misbeliefs regarding the health of their tissues may need to be addressed [22,23]. It is argued that patients who hold onto these misbeliefs are much less likely to respond favorably to PNE [20,22]. This process of undoing misbeliefs is referred to as deeducation, while teaching patients about the neurobiology and neurophysiology of their pain is reeducation [22].

In direct contrast to PNE is manual therapy. Manual therapy has by tradition a clear focus upon tissue sources of pain and dysfunction [24]. These opposing strategies have led to a dichotomy for the modern manual therapist: is PNE congruent with a hands-on or hands-off approach? [11] It seems PNE by definition, is hands-off, but can be integrated within either. We believe that various positive effects of PNE can be used in a manual therapy model, especially treating someone where the nervous system has become increasingly hypervigilant (i.e. on high alert status). The aim of this paper is to use a sensitization model to explore the place of PNE in a modern manual therapy approach.

Creating a framework: sensitization

It is now well established that a significant part of a person's pain experience is correlated with the vigilance of the central and peripheral nervous system [12,20,25]. In a subgroup of patients seeking care from a manual therapist, the central nervous system (CNS) becomes hypervigilant and poses significant clinical challenges to the use of active and passive movement strategies to normalize impairments, including techniques such as manual therapy [26–28]. Although central sensitization is not directly measureable in humans, various indirect measures are used to suggest central sensitization [25,29]. In a normal, control state, when pressure is applied to tissues, i.e. a mobilization technique to a spinal level, there is a normal tolerance (Figure 1) [30]. In the early phase of the application of pressure, light pressure is sensed as innocuous and easily tolerated by the patient. As pressure is increased, innocuous sensations progress to noxious, with a gradual increase in pain sensitivity, in line with the added noxious exposure. This model closely resembles tissues stress strain curves (i.e. Maitland, McKenzie, etc.) and grades of movement [24]. Although much refined, the original graded mobilizations differentiated between small (Grade I) and large (Grade II) movements short of resistance, and large (Grade III) and small (Grade IV) movements into resistance [24]. Anecdotally, in line with the sensitization model (Figure 1), clinicians and patients often encounter increased discomfort in these ranges of movement, as innocuous pressure progresses to noxious

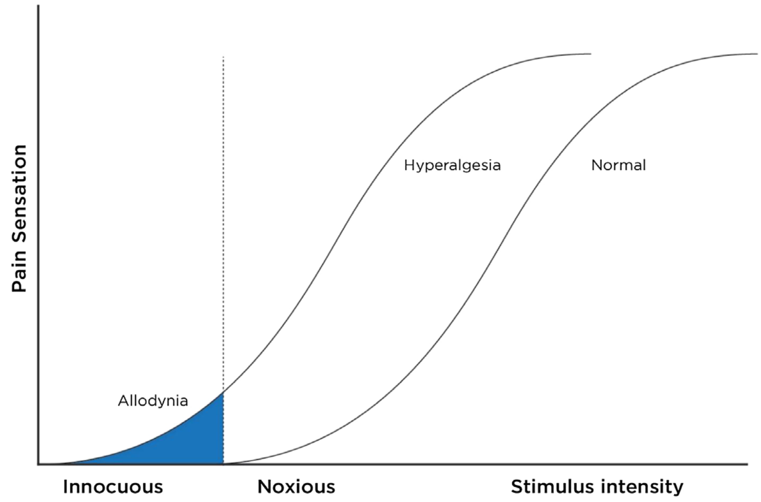

Figure 2. Allodynia and hyperalgesia's effect on pain sensation and stimulus intensity.
Note: The response curve is effectively shifted to the left so that lower intensity stimuli are more likely to produce pain sensations.

Table 1. Proposed clinical presentation of CS.

Smart, et al. [30]	Nijs, et al. [23]
Symptoms • Disproportionate, non-mechanical, unpredictable pattern of pain provocation in response to multiple/non-specific aggravating/easing factors • Pain disproportionate to the nature and extent of injury or pathology • Strong association with maladaptive psychosocial factors (e.g. negative emotions, poor self-efficacy, maladaptive beliefs and pain behaviors)	*Symptoms* • Hypersensitivity to bright light • Hypersensitivity to touch • Hypersensitivity to noise • Hypersensitivity to pesticides • Hypersensitivity to mechanical pressure • Hypersensitivity to medication • Hypersensitivity to temperature (high and low)
Signs • Diffuse/non-anatomic areas of pain/tenderness on palpation	*Signs* • Assessment of pressure pain thresholds at sites remote from the symptomatic site • Assessment of sensitivity to touch during manual palpation at sites remote from the symptomatic site • Assessment of sensitivity to vibration at sites remote from the symptomatic site • Assessment of sensitivity to heat at sites remote from the symptomatic site • Assessment of sensitivity to cold at sites remote from the symptomatic site • Assessment of pressure pain thresholds during and following exercise • Assessment of joint end feel • Brachial plexus provocation test

[22,30]. Patients often report that the pressure 'hurts good,' with various studies showing such mechanical pressure being associated with increased endogenous analgesia [10,31].

Pain, especially chronic pain, is associated with an increased vigilance of the CNS, referred to as central sensitization (CS) [25,30]. CS is defined as an increased responsiveness of nociceptive neurons in the CNS to normal and subthreshold afferent input [30]. Normal, healthy, non-threatening touch is then perceived as a threat and may increase an individual's pain experience. CS, however, is often used as a blanket term and contains two clinically important aspects of a hypervigilant nervous system: hyperalgesia and allodynia. Hyperalgesia is defined as increased pain from a stimulus that normally provokes pain, whereas allodynia refers to pain from a stimulus that would not normally provoke pain [30]. It has been proposed that CS, over time, moves from a hyperalgesic stage toward an allodynic stage (Figure 2) [30]. Various studies concur, citing a variety of peripheral and central processes such as expansion of receptor fields, neuronal death, alterations of inhibitory mechanisms, neurotransmitter changes. [30,32] .Clinically, this increased sensitization over time is well described and poses a significant challenge to manual therapists [20,33]. In the allodynic state, light innocuous manual techniques are then perceived as painful, limiting the application of manual therapy to the patient.

It is within this model that it could be argued that a strategy can be employed, whereby CS can be 'shifted' along the innocuous scale further to the right toward the noxious, lowering the threat value (Figure 2). This in turn may potentially create a 'window' for the application of manual therapy via gradually exposing patients to (hands-on) stimuli/sensory input.

Table 2. PNE's positive influence on signs and symptoms commonly associated with CS*.

	Decreased pain ratings	Increased pain tolerance	Decreased fear	Decreased pain catastrophization	Improve physical movement
Moseley [45]	+				
Moseley [46]	+				
Moseley, et al. [12]				+	+
Ryan, et al. [47]	+		0		0
Meeus, et al. [13]		0	0	+	
Vibe Fersum, et al. [48]	+		+		0
Gallagher et al. [49]	0			+	
Van Oosterwijk, et al. [50]		+	0	0	
Tellez-Garcia, et al. [51]	0	0	+		
Beltran-Alacreu, et al. [52]	0		+		+
Pires, et al. [53]	+		0		

*PNE = pain neuroscience education; CS = central sensitization.
+Indicates positive findings (improvement).
0Indicates no significant difference.

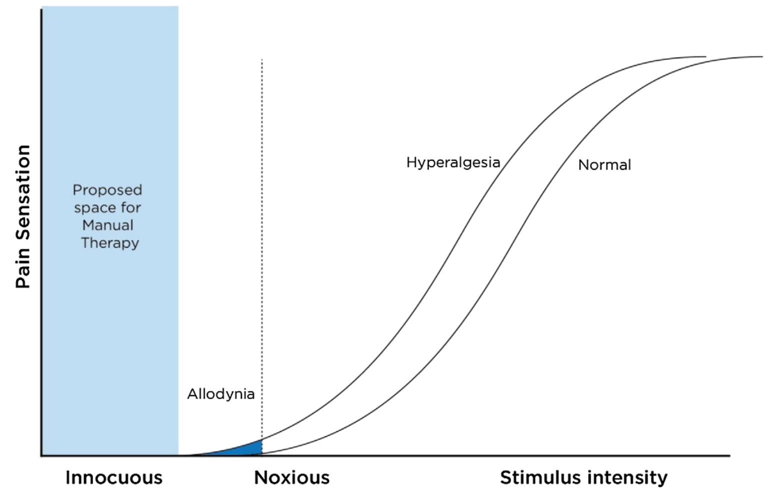

Figure 3. Proposed potential PNE shift of the stimulus intensity.

Recognizing central sensitization

The first step in exploring if a manual therapy approach can be used in a patient presenting with increased sensitivity, is the ability to recognize CS clinically. CS can dominate the clinical picture of patients with a variety of medical diagnoses, including many often seen in manual therapy practice (e.g. low back pain [34], shoulder pain [35], neck pain [36], tendinopathies [37]). Various studies have explored the clinical aspects of CS. For example, Smart et. al., used a mechanism-based classification to determine the presence of CS in patients with low back pain with and without radiculopathy, whereby three symptoms and one sign became predictive of CS (sensitivity 91.8%, 95% confidence interval (CI): 84.5–96.4; specificity 97.7%, 95% CI: 95.6–99.0) (Table 1) [33]. Nijs and colleagues, described information obtained from the medical diagnosis, combined with the medical history of the patient, as well as the clinical examination and the analysis of the treatment response in order to recognize CS (Table 1) [25]. More recently, there has been a greater focus on the use of the Central Sensitization Inventory as a means to quantify the potential presence of CS, with a score over 40 points being suggestive of CS [29,38]. The various options have been combined in a clinical algorithm for the recognition of predominant CS pain in patients presenting with 'musculoskeletal' pain [25], low back pain [39], or post-cancer pain [40,41]. With these tools and appropriate clinical reasoning, the modern manual therapist should be able to identify a patient presenting with signs and symptoms associated with CS.

Shifting central sensitization with PNE

A person's sensitivity fluctuates constantly, based on various environmental, biological and social factors [42]. Sensitization to a stimulus, e.g. touch, can increase or decrease over time, ultimately influencing a patient's pain experience [42]. This neuroplasticity provides hope for people struggling with chronic pain, and also provides a therapeutic target [43]. Pharmacologically, ion channels have become the target of various membrane stabilizing drugs, as a means to control a patient's sensitization [44]. Non-pharmacologically, various treatments have targeted aspects of CS, including sensory discrimination [27,45], transcutaneous electrical stimulation and PNE [14,20]. The evolution of PNE is rooted in physical therapy's struggles to treat chronic pain [5,7]. With our growing understanding of CS, including the various underlying mechanisms associated with the development and maintenance of CS, it can be seen that PNE was primarily developed to treat patients struggling with CS [14,20]. The most recent systematic review of PNE featured 13 randomized controlled trials using PNE for patients presenting with various musculoskeletal pain disorders commonly encountered by manual therapists [16]. A review of the RCTs included in that systematic review shows how PNE targets and positively influences various signs and symptoms associated with CS (Table 2).

If the presence of common signs and symptoms are proposed to increase the likelihood of CS, it can be argued that a lower number of factors or even the absence of these could indicate a smaller chance of CS, or a potential positive shift in CS [33]. This hypothesis concurs with studies where PNE has shown immediate changes in pressure pain thresholds (PPT) as measured by pressure algometry [14,46] .For example, in patients awaiting total knee arthroplasty (TKA), a 30-minute PNE lecture has been shown to reduce PPT on the TKA knee (local) and dominant hand (distal) following PNE (Louw, et. al. – submitted for publication). The results of the TKA study show a potential widespread change in sensitivity, which is in line with current beliefs that CS plays a significant role in knee osteoarthritis pain [47], and in line with the finding of improved endogenous analgesia (i.e. psychophysiological pain testing using the conditioned pain modulation paradigm) in response to PNE in patients with fibromyalgia [48]. The PNE session resulted in an increase in PPT at the TKA knee and hand exceeding the Minimal Detectable Change (MDC) of PPT [49]. It is within this framework that we propose PNE may shift mechanical sensitivity, thus creating a potential 'space' for manual therapy (Figure 3).

Reconciling manual therapy and pain science

We acknowledge that pain is far more complex than CS [50]. Limiting an individual's pain experience to a nociceptive event is self-limiting and should take into consideration more recent advances such as functional and structural changes in the brain, immune system changes, neglect. [28,51]. With seemingly cutting-edge advances in mirror therapy, graded motor imagery and even virtual reality, some question why clinicians would want to focus on manual therapy when it comes to treating someone in pain, especially someone in a sensitized pain state. This notion warrants further discussion. First, various qualitative studies show patients attending physical therapy rank touch and physical tests and treatments as a high priority [52–54]. In recent years, especially with the interest in pain neuroscience, attention has shifted to the importance of the therapeutic alliance (TA) [55]. TA is defined as the working rapport or positive social connection between the patient and the therapist [56]. By virtue of its definition, TA is a complex blend of therapist technical skill, verbal and non-verbal communication, sense of warmth, trust, and collaboration [56]. Aside from TA, various clinical factors of the environment, such as colors, smells and sounds, also influence the outcome of a proposed treatment [57]. The observed effects of PNE in patients with chronic pain might in part be due to its capacity to generate a TA, also because of its ability to use shared-decision-making strategies. In addition, it can be argued that human touch (manual therapy) and fulfilling a patient's expectations can enhance TA, thus, positively influencing the treatment outcome [7,11].

A second reason why manual therapy should be considered is in fact supported by the concepts of PNE. In recent years, there has been a huge shift in physical therapy toward a biopsychosocial approach. With the integration of the biopsychosocial approach into our profession, a lot of emphasis has been placed on the various psychosocial aspects of pain, which sometimes results in leaving behind the 'bio' of the biopsychosocial model [5,7]. Modern pain neuroscience addresses this issue by balancing the bio with the psychosocial dimensions of pain [26,58].

So where does PNE fit in? In a recent randomized clinical trial, manual therapists used a neuroplasticity educational model (PNE) to teach patients with chronic low back pain what a proposed manual therapy technique (central posterior–anterior mobilization grade II) was going to do [59]. In a second, biomechanical group, the same manual technique was applied, but the explanation was in line with more traditional biomedical explanations for manual therapy (hyper- and hypo-mobility). The interesting finding was that straight leg raise (SLR) showed a significant difference in favor of the neuroplasticity explanation ($p = .041$) and the neuroplasticity group were 7.2 times (95% CI = 1.8–28.6) more likely to improve beyond the MDC on the SLR than participants in the mechanical group. It is important to recognize that patients in both groups received the same manual therapy intervention, with the only difference being the explanation given to them (i.e. their understanding of what the intervention was meant to do to them in terms of their pain perception during the SLR). Although a lot more research is needed, this preliminary work shows that PNE may in fact enhance the effect of manual therapy interventions.

An educational PNE model for manual therapy

Traditionally, in manual therapy, biomechanical and anatomical models are used to explain to patients a proposed treatment or the efficacy of a certain technique or approach [60,61]. These models would imply that injury, disease, and muscle guarding may lead to altered movement patterns, asymmetrical loading, and resultant pain and dysfunction [60,61]. These biomechanical models have come under scrutiny, partly due to the advances in other

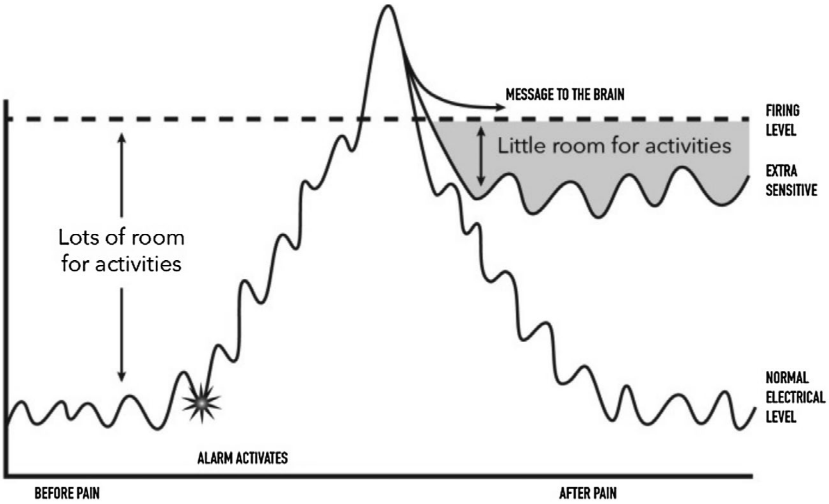

Figure 4. Metaphorical alarm system depiction of CS before and after a painful experience (Image from Louw [68] with permission).

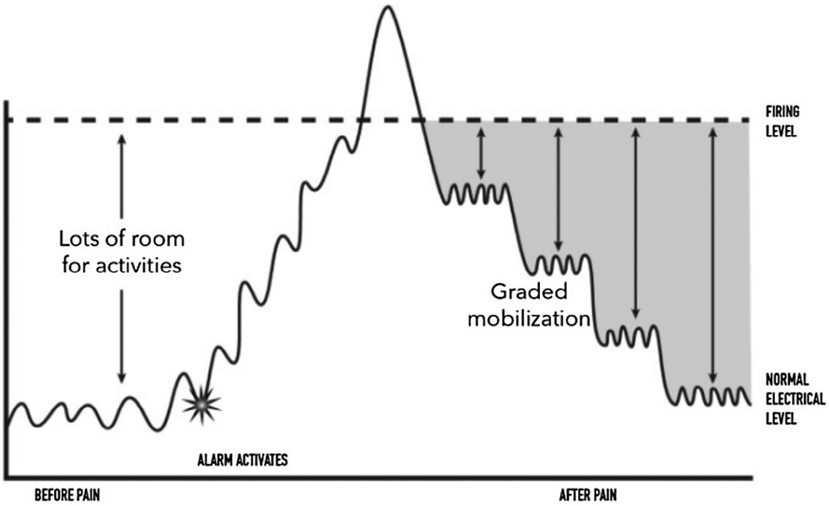

Figure 5. Using the metaphorical alarm system depiction of sensitization with the gradual increase of sensory input using manual therapy.

fields such as use of diagnostic ultrasound, spinal imaging and brain scans [31,62]. More importantly, the various mechanical explanations associated with these models are associated with increased fear and a sense of vulnerability [63,64]. This once again creates a clinical challenge for the modern manual therapist: how do we reconcile PNE and manual therapy from an educational perspective?

PNE is best delivered via metaphors, examples, and images [19,65,66]. One particular metaphor often used to help people understand CS is an alarm system [67]. In this metaphor, a patient's nervous system is compared to an alarm system, contrasting its sensitivity before and after the onset of pain [67]. In some patients, following an injury, surgery, emotional period in their life, etc., the alarm system does not calm down, thus, leaving them with an extra sensitive alarm system (Figure 4) [68].

The aforementioned discussion of CS, positively shifting via PNE, can be applied to the alarm metaphor. PNE, when used initially in the first few visits may positively influence the alarm system, dampening its sensitivity, ultimately allowing hands-on treatment. Now, with the application of a gradual increase of sensory input using hands-on treatment, a clinician may consider the use of a graded mobilization approach (Figure 5) [24].

Clinicians may encounter several practical problems when trying to combine PNE and manual therapy, including the occurrence of contradictory messages between the two interventions. If presented within a purely biomechanical model, manual therapy would not only impart patients' dependence on passive interventions (i.e. a passive coping strategy), but also come into conflict with PNE which in itself would be counterproductive. Manual joint mobilization has been shown to generate (short-term) activation of brain-orchestrated endogenous analgesia [69,70]. Hence, manual therapy should be presented to patients with chronic pain as a transient technique used to gain some movement and to facilitate activation of endogenous analgesia [11]. Manual therapy could serve as a jump start for application of other (more active) approaches like exercise or activity

Table 3. Example of the patient–therapist communication during hands-on interventions in patients with chronic pain and CS.

Therapist (T): 'Could you lie down on your back on the treatment couch so I can treat your knee? I will apply manual techniques on your knee to activate the analgesic system orchestrated by the brain that we explained last time. Do you remember that?'
Patient (P): 'Are you referring to the "spam filter" that is malfunctioning in my nervous system? Yes, I remember.'
T: 'Exactly! Applying manual techniques on your knee will temporally strengthen your spam filter, allowing you to have less pain and to move your knee better. Are you OK with that?'
P: 'Sounds good – I have to do nothing besides lying down here?'
T: 'For now that's true, but remember that my hands-on treatment can only temporally activate the analgesic system. This will last no longer than 45 minutes at best. However, there is a way to activate it longer and you can do it yourself. Do you have any idea how you can keep the spam filter activated?'
P: 'We talked last time about exercises to activate the spam filter?'
T: 'Absolutely – how do you feel about doing exercises yourself at home?'
P: 'I was expecting to do exercises as part of the physical therapy treatment anyway, so yes I'm happy to invest time in that.'
T: 'That's great. It's up to you to start doing exercises after the treatment. After I've treated you on the couch, I'll show you how the exercises work. We can try a few exercises together and design the home exercise program together. Let me start the manual treatment first.'

Notes: The therapist does not mention any possible peripheral effects of the hands-on treatment. In case patient questions the therapist about possible peripheral effects of the hands-on treatment, the therapist explains that such effects are possible but unproven, and that in any case, the brain effects (i.e. pain-relieving effects orchestrated by the brain) are far more important.

The therapist does not prepare the patient for possible side effects of the hands-on treatment (like possible pain flares). In case the patient reports pain increases during or following the treatment (either during this or the following treatment), it will be crucial to discuss them with the patient using the ideas and principles provided during the PNE.

interventions. Repetitive use of the word 'pain' during the manual treatment may come into conflict with the PNE message, where achieving functional gains is advocated over resolution of symptoms [11]. A crucial outcome of PNE is that patients become fully convinced of the fact that the presence of CS implies that the brain produces pain and other 'warning signs' regardless of changes in tissue damage or related nociception. Combining PNE with manual therapy can strengthen this message, but only if a pain-independent approach is used. Relying on pain as a guide for hands-on treatments conflicts with that message, and this in itself might induce (more) fear in the patient. Table 3 illustrates the patient–therapist communication during the hands-on interventions in patients with chronic pain and CS. Still, direct evidence supporting this view is lacking, but trials exploring them are underway.

Conclusion

As we propose this PNE approach to manual therapy, we are compelled to point out the obvious issue at hand. PNE is new in comparison to traditional mechanical manual therapy models and the traditional models are very powerfully placed in academia, clinical practice and society. Some may think PNE is only for people with CS, but what is taught to a patient in the initial phases of an injury, strongly impacts their recovery, including efficacy of future treatments, underscoring the 'de-educate to re-educate' model often seen with PNE. PNE, and more importantly PNE's merger with manual therapy, demands a powerful shift away from the stringent biomechanical models. Merely pulling out PNE for a certain patient in a rich biomechanical clinical environment is likely doomed, given the traction of the biomechanical model. PNE can be merged with manual therapy, even potentially enhance manual therapy, but manual therapy as a whole needs to shift, embracing pain science, beyond a certain subset of patients. Future research should include randomized clinical trials examining the effects of the combined PNE + manual therapy approach as proposed here, in patients with chronic pain.

Disclosure statement

The authors acknowledge receiving payments for various speaking events (seminars, conferences, etc.). AL and EP acknowledge receiving royalties from books for professionals and patients. JN has co-authored a Dutch book for clinicians on pain neuroscience education, but the royalties for that book are collected by the Vrije Universiteit Brussel and not him personally.

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