A Constructivist Framework for Understanding Pain: Beyond Representationalism

Yoshio Nakamura and C. Richard Chapman

Pain Research Center

Department of Anesthesiology

University of Utah School of Medicine

Salt Lake City, UT USA

Corresponding Author Address:

Yoshio Nakamura, Ph.D.
Pain Research Center
Department of Anesthesiology
Univ. of Utah School of Medicine
615 Arapeen Drive, Suite 200
Salt Lake City, UT 84108

Email: yn5@utah.edu
Phone: (801) 585-0419
Fax: (801) 585-7694

Introduction

While we are all familiar with pain at a personal level, pain is a topic of scientific inquiry and a major challenge in medical practice. Scarry (1985) described pain's qualities as including extreme aversiveness, an ability to annihilate complex thoughts and other feelings, an ability to destroy language, and a strong resistance to objectification. Anyone who has experienced intense pain understands her statement: while pain has sensory features and lends itself to sensory description, it is above all else a powerful negative feeling state that dominates awareness. Moreover, different people have different degrees of pain when suffering similar injuries or diseases. When pain is chronic, some people go on with life despite it while others become disabled. Thus, in addition to being complex, pain is highly individual.

This paper addresses the question of how we feel pain, in all of its rich complexity and individual uniqueness. Beneath the surface of this question is the broader, mind-body issue of how we have the experience of feelings and the nature of feelings. In Part I, we address these issues by contrasting two explanatory frameworks: sensory neurophysiology and constructivism. We assert that, by adopting the latter as a logical extension of the former, science can begin to bridge physiological structure and process to the phenomenal experience of feeling pain (Nakamura and Chapman, 2002). In Part II, we discuss the status of representationalism in pain measurement. We discuss the data from our recent study that seem to question the usefulness of psychophysical approach strictly based on representationalism.

Part I: Historical Perspectives

To date, neurophysiology has dominated scientific inquiry into the mechanisms of pain. Sensory neurophysiology focuses on the transduction, transmission and modulation of the impulse traffic that tissue trauma occasions (nociception). Information transmission and processing are central in this approach, which increasingly emphasizes the plasticity of the nervous system.

In its primitive and now anachronistic form, sensory neurophysiology construes pain as the simple appreciation of a primitive sensory message, imbued inexplicably with an unpleasant quality. Contemporary neurophysiological pain research, however, has determined that nociceptive traffic reaches the hypothalamus and the reticular formation as well as the somatosensory cortex (Burstein, Cliffer and Giesler, 1988; Burstein et al., 1991; Willis and Westlund, 1997). A substantial body of research on pain and functional brain imaging in recent years reveals that people experiencing pain demonstrate distributed central processing that involves multiple limbic and motor areas of the brain as well as thalamus and sensory cortex (Casey and Bushnell, 2000). These observations suggest that the mechanisms of emotion (the limbic brain) are active during pain.

Many neurophysiological researchers still see pain as fundamentally sensory in nature, even though people in pain manifest strong negative emotions to a much greater degree than sensations. They hold that emotions can arise in one of two ways. Either the “realization” (entry into consciousness) of nociceptive sensory signaling at the cortex generates the intrinsic unpleasantness of pain (primary pain-related emotion), or emotions can occur following the realization of sensory pain through association (secondary pain-related emotion). Secondary emotions accompanying pain are more complex than the primary emotion. The conscious sensation of pain must occur before complex emotional arousal can take place. In other words, pain is a bottom-up sensory experience, and the clinically evident emotions of pain and the related cognitions are consequent to the sensory experience.

Although this point of view advances understanding and accounts for the observations of functional brain imaging studies of pain, it suffers from three limitations: a) it construes the brain as passive and purely reactive in its processing of nociception; b) it offers no account for how pain becomes conscious and, when intense, dominates awareness; and c) it cannot explain why the fit of tissue trauma to pain report is usually poor and, in the case of chronic pain, often absent. Moreover, this perspective does not integrate naturally with ongoing, parallel research in the fields of emotion, cognition and consciousness studies.

An alternative framework grounded in consciousness studies can better account for the complex nature of pain and other feelings, and it can bridge pain research more readily to other relevant fields of study. This position, termed *constructivism*, opposes the assumption that the mind/brain maintains an accurate representation of the world based on incoming sensory information. Instead, constructivists argue, the mind/brain constructs subjective experience from sensory input, memory and expectations based on social and cultural contexts.

The Basis of Constructivism

Historically, the idea of “constructing reality” stems from Kantian epistemology and philosophy of science (Hundert, 1995). In contrast to the empiricists who asserted that we passively receive knowledge and information from the external world, Kant proposed that we construct our experience on the basis of certain innate conceptual structures (such as space, time, and causality). This notion resurfaced in Piaget’s work in genetic epistemology and developmental psychology (Piaget, 1954).

Constructivists reject many of the meta-theoretical assumptions that have long characterized cognitive science and neuroscience. They refute, for example, the notion of strictly referential representations of the body and environment in the brain/mind because it implies an isomorphic correspondence between representations and stimulus properties. Constructivism also denies that we have direct access to the properties of an objective external world; instead, the mind/brain inter-subjectively constructs the experiential world by interacting with the body and the environment. At the same time, it avoids solipsism by recognizing the interdependent nature of the mind/brain, the body, and the world. In this respect, constructivism incorporates the perspective of enactive cognition (Varela, Thompson, & Rosch, 1991).

The constructivist viewpoint asserts that the brain produces awareness from a complex array of massively parallel processes (Mandler and Nakamura, 1987; Marcel, 1983). This applies readily to the question of emotion and pain. The constructivist assumes that the brain deals, not with reality itself, but with an internal, autonomous representation of reality that it builds and revises from moment to moment, using sensory information and networks of association in memory. Subjective reality undergoes constant revision (self-organization), as it includes sensory information, emotion, ratiocination and other aspects of cognition. Furthermore, constructed reality always has a point of view. The point of view is each individual’s sense of self.

Mountcastle (1998) articulated some well-established generalizing principles in neuroscience. Two principles are important for constructivists: a) recalled memories are constructions, not replications; and 2) brain representations of external objects and events are constructions, not replications. In the field of memory, Schacter and his colleagues proposed a notion of constructive memory that emphasizes the fabricated nature of human memory (Schacter, Norman, & Koutstaal, 1998). Memory distortion phenomena such as false recognition, intrusions, and confabulations are consistent with the notion that the mind/brain constructs memory. In visual perception, for example, Hoffman (1998) described visual intelligence as the power that we use to construct an experience of objects out of colors, lines, and motions. Taken together, these emerging signs of constructivist thinking in divergent domains support the generality and usefulness of the constructivist approach. Furthermore, Riegler (2001) claims that radical constructivism (a particular flavor of constructivism) provides the foundation of a new world-view in which we can overcome many long-standing scientific problems. An excellent introduction to radical constructivism is available in the work of von Glasersfeld (1995).

Basic Assumptions of Constructivism

Three premises define our constructivist approach. First, as Mountcastle (1998) emphasized, the brain actively constructs conscious experience. Awareness is the consequence of self-organizing processes that evaluate incoming inputs against an internal model of the self and the world, and then integrate them into a coherent stable pattern with an extraordinary plasticity. This construction of consciousness proceeds in response to the intentional and situational imperatives of each person. Thus, the intentionality of the person involved in perceiving, feeling and emoting basically constrains and drives the construction of consciousness (Freeman, 1995; 2001). This process involves integrating sensory signals, memory and prior experience, expectations, and immediate and long-term goals and plans. Far from being a passive entity that merely registers information coming in from various sensory channels, the brain is an active, adaptive system that constantly “simulates” the world and the body in which it dwells.

Second, viewed this way, conscious experience resembles an attribution that each person actively constructs; it is not simply a veridical registration of information (Marcel, 1983). Conscious experience is subject to cultural influences. This way, cultural meaning systems may determine the possible range of states of consciousness.

Third, consciousness plays a causal role in the course of information processing at higher levels of the central nervous system. The causal effects of consciousness typically manifest as “constraints on” or “selections for” subsequent cycles of information processing (Rumelhart et al., 1986).

The constructivist approach escapes the narrow constraints imposed by the classical sensory neurophysiology of pain and thus makes it possible to conceptualize pain as a phenomenon of consciousness. For the constructivist, pain is a complex, emotionally negative bodily awareness characterized by sensory qualities that are normally consequent to tissue trauma.

The transduction, transmission and modulation aspects of classical neurophysiological thinking can serve as basic mechanisms for the constructivist framework. However, whereas the sensory neurophysiology framework focuses on the transmission of nociceptive impulses as specific sensory signals, the constructivist perspective emphasizes the central processing of such signals, rejecting the notion of sensory registration. The mind/brain constructs pain from complex patterns of massive, parallel distributed processing as a focal element in the perceiver’s model of the self and world.

Schemata and Construction

The schema, a perceptual hypothesis, is a fundamental unit for the construction of feeling states. Historically, the term dates back to Kant, Piaget, and Bartlett, who all contributed to the notion (Martin, 1994). Kant thought of schemata as structures of imagination that connect concepts with percepts and described them as procedures for constructing images. Later thinkers construed them as basic knowledge structures, narrative structures, or perceptual hypotheses. Some researchers see them as neural networks or patterns of physiological processes that produce consistencies in subjective experience. We view schemata as fuzzy, preconscious and dynamical, roughly related to dynamically stable patterns in neural networks. Rumelhart and colleagues usefully described schemata in this way: “Schemata are not single things. There is no representational object which is a schema. Rather schemata emerge at the moment they are needed from the interaction of large numbers of much simpler elements, all working in concert with one another. Schemata are not explicit entities, but rather are implicit in our knowledge and are created by the very environment that they are trying to interpret as it is interpreting them … ”(p. 20). As this quote indicates, schemata are active and dynamic representations that emerge out of the interactions between the perceiver and the world.

Constructivism, Pain and Feelings

Constructivist thinking suggests new ways of understanding many different clinical pain phenomena as well as many curious social rituals in which people undergo tissue damage without apparent concern. It also helps us to approach the challenge of pain control from a new perspective. In addition to attenuating nociceptive traffic in the nervous system, clinicians can, in principle, intervene in the construction of the pain experience itself. We discuss here a few of many possible applications of constructivism in the field of pain.

The schema concept helps explain post-amputation phantom feelings and phantom limb pain. Phantom limbs are kinesthetically-vivid realizations of a body part that is physically absent. Sometimes a phantom limb will hurt, and no treatment directed at the stump or administered systemically can relieve the pain (Melzack, 1990). In a study of 68 patients with amputated limbs, Katz and Melzack (1990) found that the patients acknowledged various pains, all localized to the missing limbs. The patients described these pains as immediate and real, quite unlike the recollection of a past pain state. In constructivist terms, the patients were reproducing or re-constructing the pain and not simply recalling a past event. Interestingly, some of the phantom experiences involved painless experience (e.g., feeling a shoe on a missing foot) and some had multimodal sensory qualities.

Persons with similar types and degrees of tissue damage vary from having no pain to having disabling and severe pain. Many people suffer from disabling chronic pain even though they have no definable tissue damage. Moreover, some people, when examined for other medical reasons, have severe tissue damage but do not have pain. The constructivist approach submits that each person's psychological experience differs from that of others because she or he creates, and lives with, unique experiential realities. Two persons with identical lesions do not experience the same pain because they do not have identical experiential realities. In preventing or relieving pain, it is important to fit the intervention to the psychological uniqueness of the person. Constructivist thinking may ultimately provide a rationale for the development and refinement of new psychological interventions for pain.

The constructivist approach can account for the effects of familiar psychological interventions such as hypnosis and distraction on pain (Chapman and Nakamura, 1998). These are interventions that recognize and address the complexity of human perceptual experience and the uniqueness of the individual. We propose that hypnotic suggestion alters the construction of the pain experience. The processes of competition and integration among multiple activated schemata are as viable targets for pain intervention as the neural structures and synapses that underlie nociception.

Scientifically, the constructivist approach allows us to make sense of parallel, distributed processing as reflections of ongoing dynamic competition and integration of schemata that support the construction of consciousness. Complex brain activity patterns do not readily relate isomorphically to the contents of consciousness. We suggest that distributed processing may reflect the preconscious workings of the constructive process. Combining this insight with the knowledge that the temporal resolutions of current imaging technologies constrain what we can observe in imaged data, researchers can perhaps begin to design experiments that will shed a light on how consciousness emerges out of non-conscious parallel distributed processes in the brain. Manipulation of attention, expectancy, as well as short term and long term memory may shed considerable light on the construction of pain and other feeling states when combined with functional brain imaging.

Part II: Science of Measuring Self-report of Pain

Given the critical role that self-report plays in collecting what needs to be explained involving consciousness, one might assume that we must know a great deal about *how* self-report comes about. On the contrary, we actually know very little about how our brains produce self-report. We address here some critical issues on the nature of self-report in the domain of pain measurement. We first discuss the psychophysics of pain and representationalist assumptions implicit in the application of psychophysics to pain. In order to critically examine representationalist assumptions, we discuss the determinants of the accuracy of subjective pain reports, using findings from our causal modeling study. We demonstrate that the accuracy of pain report depends in part on physiological arousal (sympathetic nervous system activation) rather than purely on an internal representation of a noxious stimulus.

Pain Measurement

Pain measurement is probably one of the most important areas for pain research and pain medicine (Chapman, 1989). Early pioneers of pain research adapted psychophysics as a guiding framework for how to go about measuring pain. Psychophysics is the science of dealing with the correlation of the physical characteristics of a stimulus (e.g., intensity, frequency, etc.) with the subjective response to the stimulus. Fechner's original ambition was to develop what he called "inner psychophysics" (relating physiology with phenomenal report), but his vision of inner psychophysics never materialized because it was too much ahead of his time. Consequently, psychophysics as we know it today corresponds to what he called "outer psychophysics" (relating stimulus with phenomenal report). Psychophysical approaches to pain measurement have succeeded in generating a substantial body of studies relating physical characteristics of nociceptive stimulus and pain sensation (Price, 1999). It is critical to spell out assumptions in the psychophysical approach to pain measurement. To do this, we need to discuss representationalism in general and proceed to reveal hidden assumptions deeply ingrained in the psychophysics of pain.

At a most general level, representationalism relates brain activity to phenomenal report in the following way. Its basic premise is that neural activity in the brain is a function of the features and causal impact of a noxious stimulus on the individual. Patterns of brain activity are internal representations of triggering events, either external or internal (somatic or visceral). In other words, the brain is reflecting the external or internal environment through such neural activity. This leads to the assumption that pain report is a function of an internal representation to which the individual has introspective access. How do we get phenomenal reports out of the individual in question? Assuming that the experience of pain is accessible to introspection, one can examine one's own immediate memory traces of sensory register. Subjective report of pain is basically an accurate translation of what one finds in the sensory register, mixed with measurement error (i.e., noise) in the system.

What is the origin of the conjecture that there must be an internal (i.e., neural) representation that correlates with conscious perception of pain? In other words, why do we believe that tracking down the neural representations that correlate with conscious experience is necessary and sufficient for understanding the nature of pain in particular and of consciousness in general? Perhaps this conjecture stems from the assumption that the discovery of perfect correlation would allow us to believe that we had identified the neural activity sufficient to produce the experience (Chalmers, 1996). Furthermore, there has been a tendency to subscribe to what Pessoa, Thompson, and Noë (1998) have called analytic isomorphism. Analytic isomorphism states that for every experience, there will be a neural substrate whose activity is sufficient to produce that experience and that there will be an isomorphism between features of the experience and features of the neural substrate (i.e., neural representations). The presumed existence of such an isomorphism makes acceptable the claim that the discovery of such a neural substrate would explain the occurrence of conscious perception.

Is this logic conceptually sound? It may be that no neural state will be sufficient to produce visual or somatosensory experience. O'Regan and Noë (2001) provide a nice analogy: "Just as mechanical activity in the engine of a car is not sufficient to guarantee driving activity (suppose the car is in a swamp, or suspended by a magnet) so neural activity alone is not sufficient to produce vision." Both analytical isomorphism and representationalism have served mainstream neural and cognitive sciences during the 20th century. Do they still remain viable to guide 21st century sciences of pain and consciousness?

Evaluating Representationalism

To examine implicit assumptions associated with representationalism and psychophysics, we focus on the question of what determines the accuracy of self-reported pain ratings. We addressed this question in our recent paper (Chapman, Donaldson, Nakamura, Jacobson, Bradshaw, and Gavrin, 2002). Note that our study addressed *the causal determinants of the accuracy of pain reports rather than the magnitude of pain reports*. Our study employed path analysis, a causal modeling statistical method that permits the examination of causal relationships among multivariate variables.

This study involved 100 volunteer subjects (56 male, 44 female). The subjects experienced three levels of noxious finger-tip electrical stimulation. The subjects did not know that there were only three stimulus intensities, delivered in random order over 144 trials. On each trial, we recorded pupil dilation, skin conductance response, heart rate, and event-related late near field evoked potentials, and collected self-reported pain ratings from the subjects in response to noxious electrical stimulation.

For the purpose of estimating the "accuracy" of pain report, we reasoned that stimulus intensity level could serve as a "gold standard" against which to judge the magnitude of the pain report. The magnitude of nociceptive signaling within the subject's nervous system should vary at least ordinally as a function of the magnitude of the electrical current delivered. Although we did not formally instruct subjects to distinguish stimulus levels in this study, their pain reports nonetheless constitute implicit numerical evaluations of the different intensities. High agreement between pain ratings and stimulus levels denotes high criterion validity, while poor agreement shows lack of criterion validity. Thus, we decided to use the term "accuracy" in a specialized sense to describe the extent of this agreement between pain rating and stimulus level (recognizing that in clinical and other settings there may be no comparable criterion against which to judge accuracy). We estimated accuracy by calculating for each subject the squared nonlinear correlation ratio (η^2), the proportion of variance in the pain report that the stimulus level can explain: $\eta^2 = 1.0 - (SS_{err}/SS_{tot})$. Cohen (1988) has provided guidelines for interpreting the sizes of squared correlation ratios. In the context of criterion validity, coefficients greater than .5

represent moderately high levels of agreement, while coefficients greater than .7 indicate excellent agreement.

The accuracy estimated by the procedures described above ranged from .07 to .91 with a median of .64. Using the criterion (.5) suggested by Cohen, we documented that the majority of the subjects demonstrated a pretty high level of accuracy. Additionally, there was no difference in the overall accuracy per se between male and female subjects. We then proceeded to investigate what determined the accuracy of pain report, using a causal modeling approach. For the present analysis, predictors of accuracy included: 1) electrical current intensity, 2) event-related late near field evoked potential (N150), and 3) arousal (overall sympathetic nervous system arousal derived from the combination of a) skin conductance response, b) pupil dilation, and c) heart rate).

==================================

Insert Figure 1 about here

==================================

Causal modeling begins with a simple theory that translates the scientific predictions into causal paths (regressions) and variable intercepts. For our model-testing sequence, we placed this initial model within a general causal hierarchy that derived from psychophysiology and current understanding of nociceptive pathways. Nociceptive stimulation clearly activates brainstem areas that in turn activate limbic structures, and direct spinohypothalamic pathways suggest that nociceptive traffic may activate a generalized, hypothalamically-mediated sympathetic nervous system arousal (Willis and Westlund, 1997; Burstein, Cliffer and Giesler, 1988; Burstein et al., 1991). Given this body of scientific understanding, we formulated the following initial set of predictions implemented in Figure 1: Stimulus level thus operated at the highest causal level, potentially determining all other responses. The N150amp could influence Arousal and Accuracy, but the converse could not occur. Arousal had a direct influence on Accuracy alone. Accuracy proved to be completely dependent, and did not affect any other variables. This general hierarchy led to the initial model appearing in Figure 1.

To further refine this broadly defined initial model, we followed a backwards elimination strategy by successively eliminating statistically insignificant features of the initial model, until a final model remained that contained only statistically significant parameters. At the last model-testing step, no insignificant parameters remained and we accepted that model as the final characterization of the determinants of accuracy. Figure 2 presents the final model.

The final model revealed a direct causal chain that links stimulus Current and Accuracy. First, stimulus Current determined the amplitude of N150, where N150 may possibly an indicator of attention. Second, N150 amplitude in turn determined the magnitude of Arousal. Third, Arousal turned out to be the unique determinant of the Accuracy of the pain report.

==================================

Insert Figure 2 about here

==================================

At each step of model testing, we sought to determine if a causal link in question differed across the male vs. female subjects in the study. There was a significant difference by sex on the magnitude of causal linkage between Arousal and Accuracy. Men who experienced higher levels of arousal produced more accurate pain reports than those who had lower levels of arousal. In contrast, women who had higher levels of arousal produced less accurate pain reports than those who had lower levels of arousal. The finding warrants further investigations of why male and female subjects may differ in the relationship between Arousal and Accuracy of pain report.

Making Sense and Casting Doubt on the Status of Representation

First, what does the evidence that Arousal determined Accuracy imply? Taken at a face value, it does not seem to support the conjecture that the accuracy of subjective pain report should depend on an internal representation of a noxious stimulus. Of course, this interpretation critically relies on what we mean by an internal representation of a noxious stimulus. If an internal representation of a noxious stimulus is what the brain accurately “registers” in response to noxious stimulation, whatever this representation might be, then it does not seem to determine the accuracy of self-report. This is the sense in which most pain researchers refer to a representation as the representation of tissue injury or trauma. Given this definition, the nature and magnitude of this representation should determine the accuracy of subjective self-report of pain. Data from causal modeling analyses do not fit this assumption.

If an internal representation of noxious stimulus includes sympathetic nervous system activation (arousal) as its essential feature, then one can argue that this modified internal representation seems to determine the accuracy of self-report, and consequently one can still hold onto the dominant representationalist Zeitgeist. However, making this move effectively violates what representationalist assumptions implicitly or explicitly entail, namely, the characteristics of a noxious stimulus are the properties of the noxious stimulus, independent of the person feeling pain.

Engel (1999) reviewed the field of visual neuroscience and reached a similar conclusion characterizing representational accounts of visual perception. First, vision consists of recovering a pre-given world and constructing an internal image of the world. Second, relevant structures of external world are observer-independent and defined irrespectively of any cognitive activity of an agent. Representationalism and its conceptual foundation, analytic isomorphism, have been the main engines that have driven psychophysical approach to pain measurement. Are we poised to question the metaphysical dogma of analytic isomorphism?

Beyond Isomorphic Representation

The notion of representation is central to our understanding of how the mind/brain works in both cognitive science and cognitive neuroscience (Clark, 1997; deCharms and Zador, 2000). Among scientists working in these disciplines, the consensus exists that both brains and computer models are presumably housing "internal representations." What is a function of these internal representations? As Miller and Freyd (1993) succinctly stated, "the strengths of representationalism have always been the basic normative conception of how internal representations should accurately register important external states and processes" (p. 13).

Reviewing the concept of representation in both neurophysiology and neuroscience, deCharms and Zador (2000) similarly affirmed the central importance of representation in these fields. According to them, representation is defined by two principal and overlapping characteristics, namely, content and function. Content is the information that a representation carries. In fact, deCharm and Zador argue that content is a principle hallmark of neuronal representations. In contrast, function is the effect the representation can have on cognitive process and resultant behavior. The function of neural representation is to provide a highly correlated and information-rich mirror of the environment and to support adaptive behavior (Churchland, Ramachandran, and Sejnowski, 1994). It is interesting to note that this notion of internal representation really fits the metaphor of "mind as mirror": the mind/brain accurately reflects frequently occurring regularities of the external environment.

What seems uniform across these two views is the strong dependence upon internal representation as a vehicle for representing the content of consciousness. The thesis of internal representations runs deep in contemporary sciences of the mind/brain. Working from perspectives of inner psychophysics, we demonstrated that representationalism reflected in psychophysics seemed to fail to account for causal modeling data from our multivariate psychophysiological study of noxious stimuli. Are we alone in questioning the status of internal representation? Investigators working in several different areas associated with consciousness (i.e., O'Regan and Noë (2001); Freeman, 1995; 2001) have begun to question the notion of internal representation strictly couched in the representationalist framework. Perhaps these emerging trends in consciousness studies suggest that evidence will ultimately force us to re-evaluate the question of how the brain "represents" pain in particular and subjective states in general.

Representationalist assumptions have dominated the field of pain research and have led to the critical conjecture that the person in pain examines the contents of consciousness before making a report about the sensory or affective magnitude of pain experience as well as about its nature. We submit that the data discussed here are inconsistent with the representationalist assumptions. It remains to be seen in the next several decades whether the 21st century sciences of pain will illuminate how the human brain generates subjective self-report of pain. We believe the constructivist approach we briefly sketched in Part I will guide our explorations of this challenging problem in interdisciplinary studies of pain and consciousness.

Conclusions

We have asserted that all experience, including pain and other feeling states, is the end product of the construction of consciousness. Transduction, transmission and modulation are contributory processes. As such, they are necessary for a comprehensive scientific account of pain and emotion, but they are not in themselves sufficient. The highly individual nature of pain and personal feelings derives from unique nature of processes involved in the construction of consciousness.

Constructivism has strong implications for pain assessment and management in medicine. Classical neurophysiological theory justifies the search for a straightforward cause of a pain, but constructivism indicates, as everyday medical experience demonstrates, that such correspondence is unlikely to occur. It also suggests that the construction of pain and other negative emotional states is a viable target for prevention and intervention.

We suggest that the concept of pain mechanisms in medicine is too narrow and constrains the development of effective new avenues for pain prevention and relief. Pain is consciousness-dependent phenomenon, and its mechanisms must extend to include those of consciousness itself. Constructivism offers a framework for extending future understanding and control of pain to new horizons.

References

Burstein, R, Cliffer, K.D. and Giesler, G.J. (1998). The spinohypothalamic and spinotelecephalic tracts: direct nociceptive projections from the spinal cord to the hypothalamus and telencephalon. In R. Dubner, G.F. Gebhart, and M.R. Bond (eds.), *Proceedings of the 5th World Congress on Pain*. New York: Elsevier, pp 548-554.

Burstein, R., Dado, R.J., Cliffer, K.D. and Giesler, G.J. (1991). Physiological characterization of spinohypothalamic tract neurons in the lumbar enlargement of rats. *Journal of Neurophysiology*, **66**, 261-84.

Casey K.L. and Bushnell M.C. (2000). Pain Imaging: Progress in Pain Research and Management, Vol. 18. Seattle, WA: IASP Press.

Chalmers, D. J. (1996). *The conscious mind: In search of a fundamental theory*. New York, NY: Oxford University Press.

Chapman, C.R. (1989). The concept of measurement: coexisting theoretical perspectives. In C.R. Chapman and J.D. Loeser (eds.), *Issues in Pain Measurement*, New York: Raven Press, pp 1-16.

Chapman C.R., Donaldson D.W., Nakamura Y., Jacobson R.C., Bradshaw D.H., & Gavrin J. (2002). A psychophysiological causal model of pain report validity. *The Journal of Pain, 3(2)*, 143-155.

Chapman C.R. & Nakamura Y. (1998). Hypnotic analgesia: A constructivist framework. International Journal of Clinical and Experimental Hypnosis, XLVI(1*),* Hypnosis in the relief of pain: Part II: p.6-27.

Churchland, P.S., Ramachandran, V.S., and Sejnowski, T.J. (1994). A critique of pure vision. In C. Koch and J.L. Davis (eds.), *Large-Scale Neuronal Theories of the Brain*. Cambridge, MA: MIT Press.

Clark, A. (1997). *Being There: Putting Brain, Body, and World Together Again*. Cambridge, MA: MIT Press

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. Hillsdale, NJ: Lawrence Erlbaum Associates.

DeCharms, R.C. and Zador, A. (2000). Neural representation and the cortical code. Annual Review of Neurosciences, **23**, 613-647.

Engel, A.K. (1999). Paradigm shifts in cognitive neuroscience: from algorithmic to situation cognition. Paper presented at the workshop “The Brain and its Sciences”, MPIWG Berlin, Nov. 25-28.

Freeman, W.J. (1995). *Societies of Brains*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Freeman, W.J. (2001). *How Brains Make Up Their Minds*. New York, NY: Columbia University Press.

Hoffman D.D. (1998). Visual Intelligence: How We Create What We See. New York: W. W. Norton & Company; 1998.

Hundert E.M. (1995). Lessons from an Optical Illusion: On Nature and Nurture, Knowledge and Values. Cambridge, MA: Harvard University Press; 1995.

Katz J. & Melzack R. (1990). Pain 'memories' in phantom limbs: review and clinical observations. Pain, *43*(3), 319-336.

Mandler G. & Nakamura Y. (1987). Aspects of consciousness. Personality and Social Psychology Bulletin, 13:299-313.

Marcel A. (1983). Conscious and unconscious perception: Experiments on visual masking and word recognition. Cognitive Psychology, 15:197-237.

Martin B. (1994). The schema. In: Cowan G, Pines D, Meltzer D, editors. Complexity: metaphors, models and reality. Reading, MA: Addison-Wesley, p. 263-285.

Melzack R. (1990). Phantom limbs and the concept of a neuromatrix. Trends in Neuroscience, 13:88-92.

Miller, G. and Freyd, J. (1993). *Dynamic Mental Representations of Animate Motion*. Cognitive Science Research Paper 290, University of Sussex.

Mountcastle V.B. (1998). Brain Science at the Century's Ebb. Daedalus, Vol. 127(2), 1-36.

Nakamura, Y. & Chapman, C.R. (2002). Constructing pain: How pain hurts. In K. Yasue, M. Jibu, and T. Della Senta (Eds.), *No Matter, Never Mind: Proceedings of Towards a Science of Consciousness: Fundamental Approaches (Tokyo '99)*. Philadelphia: John Benjamins Publishing Company, pp. 193-205.

O'Regan, J.K. and Noë, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences, 24*, 939-1031.

Pessoa, L., Thompson, E., and Noë, A. (1998). Finding Out About Filling In: A Guide to Perceptual Completion for Visual Science and the Philosophy of Perception. *Behavioral and Brain Sciences*, **21**, 723-748.

Piaget J. (1954). The Construction of Reality in the Child. New York: Basic Books; 1954.

Price, D. D. (1999). *Psychological Mechanisms of Pain and Analgesia*. (Vol. 15). Seattle: IASP Press.

Riegler A. (2001). Towards a Radical Constructivist Understanding of Science. Foundations of Science, 6(1-3), 1-30.

Rumelhart D.E., Smolensky P., McClelland J.L., & Hinton G.E. (1986). Schemata and sequential thought processes in PDP models. In: McCleeland JL, Rumelhart DE, editors. Parallel Distributed Processing: Explorations in the Microstructure of Cognition, Vol 2: Psychological and Biological Models. Cambridge, MA: MIT press. (p. 7-57)

Scarry E. (1985). The Body in Pain: The Making and Unmaking of The World. New York: Oxford University Press.

Schacter D.L., Norman K.A., & Koutstaal W. (1998). The cognitive neuroscience of constructive memory. Annual Review of Psychology, 49:289-318.

Varela F., Thompson E., & Rosch E. (1991). The Embodied Mind. Cambridge, MA: The MIT Press.

von Glasersfeld E. (1995). Radical Constructivism: A Way of Knowing And Learning. London: Falmer Press.

Willis, W.D. and Westlund, K.N. (1997). Neuroanatomy of the pain system and of the pathways that modulate pain. *Journal of Clinical Neurophysiology, 14*, 2-31.

Figure Legends

Figure 1. Path diagram illustrating the Initial Model for causal analysis. Parameters of the model are not shown for simplicity.

Figure 2. Path diagram displaying the Final Model. The numbers on the arrows indicate regression coefficients characterizing linear linkages, and there was no difference between male and female subjects. However, there was a significant difference across the two groups in the last linkage between Arousal and Accuracy. Regression coefficient for the male group was .25, while that for the female group was -.36.

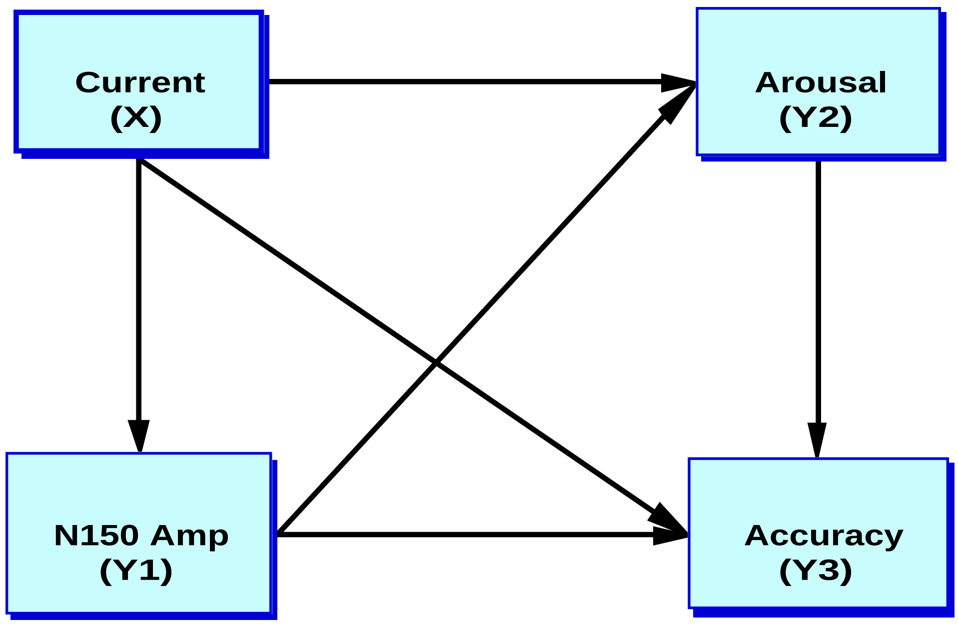

Figure 1

Path diagram illustrating the Initial Model for causal analysis

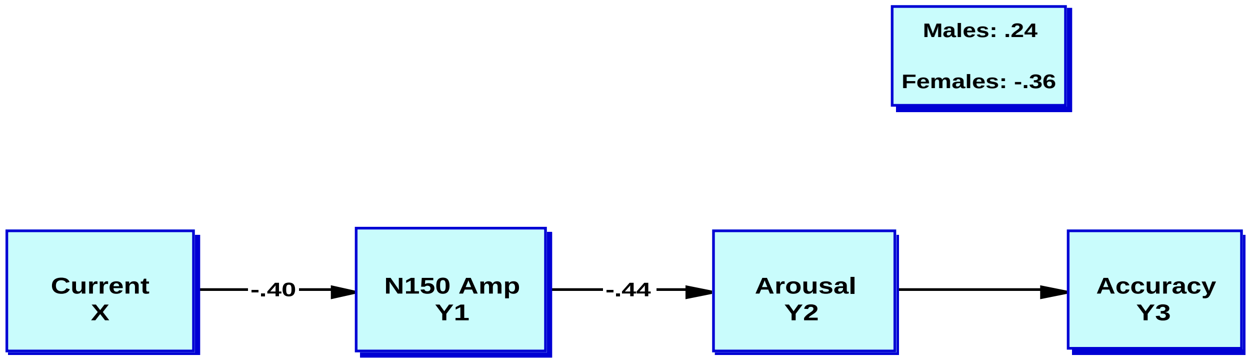

Figure 2
Path diagram illustrating the Final Model