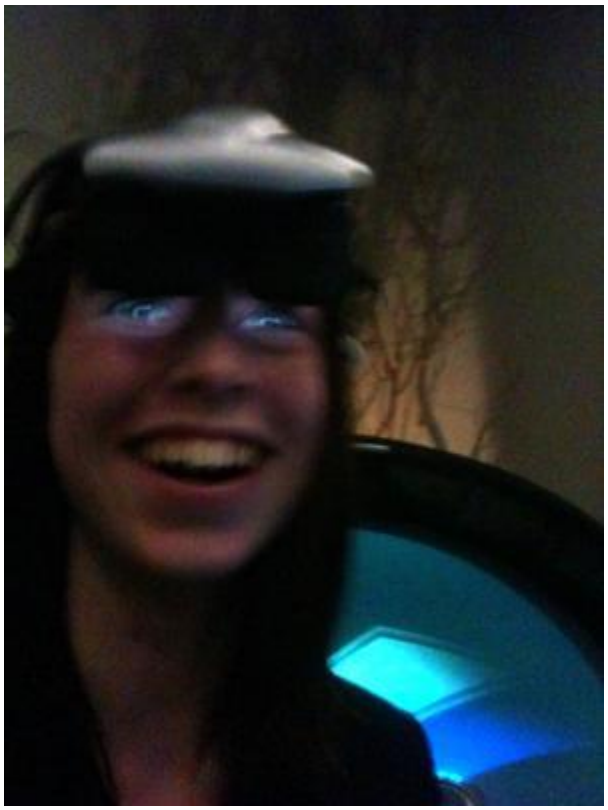
METAPLASTICITY & INNER BODY SCHEMAS: VR FOR CHRONIC PAIN

DIANE GROMALA

This paper describes a new paradigm of VR created for chronic pain that turns ideas of pain distraction inside-out. This paradigm enables manipulation of inner states, emphasizing the role of aesthetics in therapeutic contexts. We propose that this paradigm extends ideas of body image and schema and dissociative states, providing evidence that managing inner states is possible, a process referred to as meta-neuroplasticity.



The three VEs developed to address chronic pain integrate immersive VR with biofeedback, which serves as a primary means of navigation. The VEs are designed to help immersants become aware of and to gain agency with their inner states in an effort to remap their pain and body schema. Copyright Diane Gromala, 2010.

Pain[s]

Pain is a boundary condition – a non-normative experience that can alter one's perception, distorting it beyond all imaginings. By understanding boundary conditions in more depth, the Transforming Pain Research Group (TPRG) believes that more normative states may be more fully understood.

All humans experience pain[1], an essential warning system that alerts us to injury or disease. Like the historical figure of the pharmakon, pain is indeterminate, unquantifiable and beyond language. When intense, pain is beyond sharing, causing one to curl into oneself in a primal way, stripping away, bit by bit, our most basic feature as a social creature: our ability to communicate or connect with other humans. In The Body in Pain: The Making and Unmaking of the World, Elaine Scarry explains that pain ". . . unlike any other state of consciousness – has no referential content. It is not of or for anything. It is precisely because it takes no object that it, more than any other phenomenon, resists objectification in language" [2]. Pain bears other paradoxes: certain kinds, such as childbirth pain, work in tandem with other biochemical actions, and are thus dimly remembered; other forms, like chronic pain, prevent the kind of forgetting that habituation usually enables [3].

Chronic pain is a category of pain that significantly differs from acute or short-term pain. Acute pain is a symptom of a disease or injury; once the originating disease or injury is cured, acute pain subsides. In contrast, chronic pain is defined as a disease, an on-going, degenerative state [4] in which the pain response systems remain 'stuck' in high gear. Although chronic pain affects, by conservative estimates, one in five people in so-called industrialized countries [5], little is known about its causes or mechanisms. Because chronic pain cannot be cured, the emphasis is on managing this usually lifelong kind of pain.

Background

1991 marked the seventh year I had unremitting, chronic pain. What seemed like a hundred odysseys in search of even temporary ease led, in that year, to two parallel experiences – universes apart, they nevertheless were what neuroscientists term dissociative states. Far from out-of-body travel, they were scramblings of inner and outer sensations, a fluid, otherworldly state that I glimpsed in meditative practices. These practices enabled me to 'remap' my pain, a hard-won ability, to put it in the background of figure/ground experiences that comprise my moment-to-moment, everyday states.

The first of these two experiences was at the Blue Mosque, during a sunny afternoon in Istanbul. The second was in a computer lab in the Banff Centre for the Arts in Canada. In a kind of fate that is too unbelievable to concoct, I was able, to combine and recreate these experiences in an artwork I produced with Yacov Sharir in Dancing with the Virtual Dervish: Virtual Bodies [6]. One of the very first VR artworks, this collaborative effort was continually refined over a decade. The virtual world that immersants experienced was a torso, derived from an MRI of my torso that physicians insisted on in some quixotic quest to 'verify' that some non-existent biomarker of a disease or injury was the cause of my pain [7]. By recontextualizing this torso as a virtual environment (VE) to inhabit, Sharir and I strove to create virtual worlds to inhabit in unfamiliar ways. The VE comprised continuously decaying and reforming skeletal bones that defined a non-rectilinear space, while smaller organs revealed unexpectedly immense and abstract worlds.

Although we created this work at the height of technological discourses favoring a disembodying view, ours countered it. In our view, the new sensations of 'flying' while simultaneously feeling the tug of gravity, or of becoming aware of proprioception, were experiential states that one could not easily brush away into the bin of disembodied experience. This appears to have escaped art critics at that time, perhaps because the notion of transcendent or dissociative states seem to be predicated on an assumption that one is leaving one's body, not experiencing it in new ways.

Throughout the next two decades, I explored multiple ways in which diverse technologies could provoke non-normative states that brought usually quiescent, inner sensations to the foreground of awareness, from interactive books made of meat [8] and typographic fonts that changed according to one's biofeedback to evolving forms of VR [9]. Although the TPRG investigates other technologies from robotics to social media, VR is currently our main focus, in part because prior and current research makes it clear that VR provokes or opens access to inner sensations in multiple and persistent ways.

Immersive VR

Building on our experience in creating well-known virtual environments designed for artistic [6], cultural heritage [10] and medical applications [9], we examine the affordances of immersive VR through a fundamental human experience – pain. Known strategies for managing chronic pain necessitate that we design systems which bring inner senses to the foreground of awareness, and sometimes are seemingly exteriorized so chronic pain patients may learn how to remap their pain in sustainable ways.

Although virtual reality is admittedly an unfortunate term, artists and others working in videogames and online communities such as Second Life redefine the terms 'virtual' and 'immersive,' eliding the longstanding distinction between screen-based work and immersive VR as defined by its originating disciplines, or they perhaps mix ideas of social presence with immersion [11].

VR differs from 3D videogames and online communities, however, in the complexity and affordances of its integrated technologies, including interactive stereoscopy, spatialized sound, haptic force-feedback and six degrees of freedom, among others. But the most important distinctions are experiential: in VR, attention is far more directed, and the human sensorium – interceptive and exteroceptive – is tightly bound in technological entanglements, or what computer scientists term feedback loops. And although much of the focus is on experiences manifested within the VE, these experiences persist beyond it. The use of immersive VR for training pilots and surgeons illustrates the profound degrees to which our embodied processes are affected in long-term ways that alter perceptual, neurological, sensorial, autonomic and other systems. The brain and nervous system were believed to have been set in adulthood; however, their long-term malleability that results in structural changes is now recognized as meta-neuroplasticity.

Although similar phenomena may be observed in other media forms, immersive VR maintains specific affordances that are important to explore. The intensity of sensorial and embodied perceptual involvement in VR remains profoundly and measurably different. For these reasons, I maintain the longstanding distinction between immersive VR and other interactive, 3D work.

Pain and VR

The tendencies to create enhanced, unfamiliar and dissociative experiences, and to explore boundary conditions, have deep roots in human history: we have carved out spaces, places and environments; created communal experiences and practices; and ingested opioids, hallucinogens and now-common mood-altering drugs [12]. It is, therefore, perhaps no surprise that humans have developed technologies that function similarly.
Over the past decade, immersive VR has been explored as a non-pharmacological analgesic [13], a sensorially-rich method of 'pain distraction' for attenuating acute pain. This directing of attention outward

proved to be more effective than videogames in reducing pain, and provocatively, is on par with opioids. Simultaneously, V.S. Ramachandran's research in how chronic pain may relate to body image and body schema grew from his use of mirrors to produce analgesic effects for phantom pain[14]. The profound effectiveness of mirrors in alleviating phantom pain led to the acceptance of of mirrors as the first instance of 'VR' for pain [15].

Still other forms of technology initiated by Paul Bach-y-Rita enable sensory substitution [16]; this further demonstrated that our neurological systems are plastic or not as hard-wired as was once believed.

Current Work

Currently, our three works-in-progress are varied VEs createded to address chronic pain. The first, nearing completion, is the Virtual Meditative Walk, an extension of our prior work, the Meditation Chamber [9]. It integrates VR with biofeedback and a treadmill to train immersants in mindfulness meditation. Both biofeedback and mindfulness meditation have proved to be effective in treating chronic pain [17] through 'self-modulation.' In studying the different forms of meditation across cultures, we chose walking meditation [18] because many who have chronic pain become less active, a phenomenon referred to as kinesiophobia. In the Virtual Meditative Walk, immersants slowly walk on a treadmill while their GSR (galvanic skin response) and HRV (heart rate variability) data are fed into a computer. This data drives the visual, binaural and spatialized sonic elements in real-time. Immersants see a 3D forest that changes form in response to moment-to-moment changes in their physiological data. Immersants also initially hear a vocal 'coach' that guides them through the method of walking meditation.

We are concurrently developing two other prototypes that use similar biofeedback as a method of interaction. Cool! is a snowy world, created in partnership with Firsthand. Seated immersants develop skill in meditating – the more they approach a meditative state, the higher they 'hover,' to about a meter above the terrain. The VE becomes progressively non-realistic, designed to enhance a sense of weightless 'floating' that is often noted by experienced meditators.

Both prototypes comprise several phases. The first phase is designed so that immersants may discover the cause-and-effect relationships between biofeedback and those aspects of the VE that respond. An important issue that remains unexplored by others is that when those who have chronic pain try to meditate for the first time, their awareness of their pain tends to temporarily spike. To address this, we designed non-normative experiences, such as hovering or manipulating proprioception. Proprioception, the sense of where we are in our bodies and where its boundaries may be, affects one's body schema. We think that the unfamiliar experience of distorting proprioception may help immersants manage their initial spike in pain, and may help them discover that they can learn to self-modulate their pain by remapping their body schema. Initial tests appear to confirm that this approach indeed works [9]. The aesthetics of the VE are crucial here, for artists are arguably expert in creating otherworldly or non-normative experiences that are compelling enough to evoke one's sense of proprioception.

Through this work, we have found that visuals tend to pull one's attention outward, while non-linguistic sound seems to remain in an ambient or background relation to attention. Thus, the second phase promotes a transition of focus from the visual to the sonic. It is in this phase that immersants accrue their greatest skills in meditation practices.

The Sonic Cradle, our third and fully developed VE, is predominantly sonic, and does not incorporate any visuals. Immersants sit in a suspended, semi-reclined hammock. They are told little except that they should breathe slowly and regularly from the belly, which alters sounds in real time. When they hear a sound they like, they hold a deep breath in order to 'add' that sound to the on-going sonic composition. Immersants don't know that this VE is built upon Kundalini Yoga practice and theory. The sounds spatially rotate counter-clockwise among four speakers, while a sub-woofer vibrates the pelvis. According to principles of Kundalini Yoga, rotating sound in this way enhances our body's electric field. This system is designed for immersants to add sounds and repetition in order to drive this field up and out toward the ceiling. While little scientific evidence has verified this phenomenon, initial participants report that they feel deeply relaxed and 'float' upwards, which they describe as mildly euphoric. These reactions are probably not responses to any known intention of the system design, since no references to mediation or yoga are made.

Neuroplasticity: Persistent & Intentional Change

In the wider, related arenas of VR research, the process and role of gaining skills to intentionally manipulate inner or interoceptive senses – besides exposure therapy – has rarely been explored. Although 100,000 times more of our resources are dedicated to sensing inner states, compared to those for the five exteroceptive senses [19], our inner states are necessarily quiescent, lest they overwhelm our awareness [20]. Yet humans have the ability to learn how to access and consciously affect some of these inner states, as evinced by yogic traditions, biofeedback and newer technologies with intensive practice, these skills result in longterm changes.

Unlike pain distraction, which is useful for acute pain, the TPRG developed a different paradigm designed to enable those with chronic pain to learn both biofeedback and mindfulness meditation. Both are skills that persist beyond VR, and are standard in managing chronic pain. Obviously, technology is unnecessary for learning how to meditate. However, it provides real-time feedback, which our subjects report is important for learning, and reduces frustration in not knowing if they are making progress [9]. The tight feedback loops and multiple perceptual and sensory modes engaged by VR appear to enhance skill acquisition, according to over 400 immersants [ibid]. Finally, skills acquired in a VE are known to persist. With practice, we believe it is possible for immersants to make long-term meta-neuroplastic changes that may dampen pain levels. Therefore, we are using standard pain research methods to measure pain thresholds.

Our design of these VR systems takes the knowledge of media producers, interactive artists and sound designers as fundamental. Through extensive preparatory interviews and participation by patients, we have learned that in the first phase the VEs must act in direct response to immersant's changing inner states. In other phases, however, the VE functions better as a counterpoint. The visuals and sounds are emphasized and de-emphasized, according to the ways immersants respond.

We have also learned that expectations based on knowledge of other media do not directly translate in immersive environments. For example, when walking and meditating, a meditator learns not to become

distracted by visuals. They concentrate on what it feels like to step forward, using their peripheral vision as an ambient guide. Thus, while we believed that fog would parallel this experience, we found the inverse to be true. Therefore, we are developing principles derived from interactive art, media studies, perceptual science and neuroscience. None provide working principles in isolation, yet their combination appears to work. At present, we are focusing on ideas from the nascent area of neuroaesthetics, particularly by creating a VE to work with and against body image and schema, and by drawing upon aesthetics from Indian and Middle Eastern samas. It is important to note that the ways in which chronic pain affects experience foregrounds our work. For example, those who have chronic pain are often sensitive to certain kinds of sound, and have issues with moving and anxiety, among other factors.

Finally, while recent technological advances have dramatically reduced the cost of VR, it remains relatively complex and inaccessible. Thus, we are testing our systems in physicians' clinics and hospitals so that chronic pain patients will not need to travel to another site. Further, these systems are being extended to home computers and mobile devices, both to reinforce the VR meditation sessions, and to track progress, compliance and changing pain levels.

User testing includes both qualitative and quantitative methods, drawing upon the varied expertise of each researcher. It is particularly fortunate that the preponderance of wider research in chronic pain is based on a biopsychosocial model. While the group members work together to create the VR systems and methods of testing, each member also examines ideas within their particular domain. This approach prevents any one disciplinary bias from dominating, yet allows for concurrent research in each discipline.

Conclusion

Because VR has been successfully used in therapeutic realms, including treating acute pain, numerous researchers have called for the development of VR to address chronic pain [15]. The TPRG is the only group we are aware of that focuses specifically on VR for chronic pain. The VEs we create are designed to help immersants with chronic pain to learn biofeedback and mindfulness meditation techniques. These are long-term, intensive skills which, when practiced, are effective ways of self-managing chronic pain. We verified that the affordances of VR provide real-time feedback that enhances skill acquisition, and are investigating how the roles of dissociative experiences may help initial spikes in pain, and in learning to remap relations between pain and body schemas. Our paradigm runs counter to methods of pain distraction, since it is unreasonable to spend all wakeful hours in VR. By focusing on learning skills to self-modulate inner states, we believe this paradigm may extend knowledge of VR as it relates to body image, body schema, dissociative states, chronic pain and pain self-management. The focus on the aesthetics of VR distinguishes this work from other therapeutic uses of VR. Finally, if our paradigm proves successful, we believe that what is learned in VR and practiced outside of it may persist in ways that reduce pain levels and may result in structural, meta-neuroplastic changes.

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