The Effects of Sport-Specific Virtual Reality Conditions on Attention and Pain in Healthy Baseball Athletes

Steven Warsh

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By: Steven Warsh

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Signed by the final examining committee:

______________________________ Chair
Dr. Andreas Bergdahl

______________________________ Examiner
Dr. Maryse Fortin

______________________________ Examiner
Dr. Mathieu Roy

______________________________ Thesis Supervisor
Dr. Geoffrey Dover

Approved by ______________________________
Dr. Maryse Fortin, Graduate Program Director

August 28, 2024 ______________________________
Dr. Pascale Sicotte, Dean of Faculty Arts and Science

Abstract for Masters

The Effects of Sport-Specific Virtual Reality Conditions on Attention and Pain in Healthy Baseball Athletes

Steven Warsh, MSc

Virtual reality is no longer a dream, the future is here. Virtual Reality (VR) offers endless potential for individualized rehabilitation for patients and previous research has established use-cases for multiple sclerosis, spinal cord injuries, burn victims and stroke patients. With respect to sports, VR studies have primarily been focused on training skills or rehabilitation for injured soccer athletes. There is a lack of research on VR's use as a rehabilitation tool for ball sport athletes. This study aimed to investigate whether health care professionals could use VR for injury rehabilitation as a pain management, immersion and flow tool on these athletes. We conducted a within-subjects design to investigate the effectiveness of VR as a distractor from chemically induced pain by Capsaicin, mimicking real injuries, using a sample of Canadian baseball athletes. Our research questions focused on investigating to what extent being immersed in a sport-specific activity had on how much flow and immersion was experienced, thereby reducing pain even greater than a non-sport specific activity. We randomized the order of three tasks, a non-baseball computer condition (Two-Back), an easy VR baseball practice condition and a challenging hard VR baseball game condition. While the results showed a decrease in pain, they were not statistically or clinically significant. However, our results did show that VR conditions produced a statistically significantly higher and comparable level of immersion and flow for both difficulties, when compared to the Two-Back task. For clinicians who want to immerse an athlete in their sport outside of the field of play, this research shows that Virtual Reality is a valid option.

Keywords: Virtual Reality, VR, XR, Pain, Baseball, Rehabilitation, Athletic Therapy, Injury Rehab, Flow, Immersion,

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Introduction

Virtual Reality (VR) is a breakthrough technology that could be used as a significant non-pharmacological treatment for the reduction of pain and rehabilitation of athletes. The opioid epidemic is a real North American tragedy and opioid related drug-overdose deaths rose 30 percent during the first year of the pandemic alone.[1-2] Virtual Reality will not end the epidemic, but research is important to find non-pharmacological treatments for pain. As an example, burn victims using immersive Virtual Reality had a significant reduction in pain when compared to opioids.[2] Researchers attributed this reduction to the fact that VR immersion was constant, whereas opioids are taken once.

VR has been implemented in many other use cases. In November 2021, the Food and Drug Administration approved the first use of VR as a medicine to be commercialised for the management of chronic pain. Virtual Reality has been effective for lowering both experimental pain and the discomfort related to dental care.[2] Researchers have shown that VR has the potential to help with conditions ranging from anxiety and depression to stroke rehabilitation, to surgeons strategically planning where to cut and stitch.[1,3,4] However, it remains to be established how VR is effective in reducing pain, and whether VR can be used effectively for athletes recovering from injuries.[5]

Virtual Reality is the best method for captivating attention, immersion and reaching a state of flow which might be very effective in athletes.[1] The brains limited ability to prioritize attention to multiple stimuli, known as the limited resource model of attention, is believed to be the major factor in why VR reduces pain.[6] For example, one study with a healthy population of undergraduate volunteers found that greater pain reduction was associated with use of high-tech equipment that enhances immersion in the virtual environment from increased stimuli and realism.[7] Flow and immersion are two states that require significant attention and focus to attain.[8] Researchers note that VR can provide athletes with a highly immersive and realistic experience, which can increase their engagement and sense of control during training and competition.[8] For the majority of performance measures, the adaptive baseball virtual environment training group showed a significantly greater improvement from pre-post training as compared to the other groups.[9]

The decision to create a laboratory-based experience allowed for the use of a controlled setting, as opposed to the variable nature of real-world injuries. For us, establishing a controlled setting was critical for doing research in such a unique and complex study. If the study was completed using injured athletes as participants, the subjectivity and unpredictability of pain would be difficult to control and correctly assess. Previous research has established the role of attention on pain intensity ratings in Capsaicin-induced experimental pain.[10] In another lab-based study, researchers noted that experimental pain induction occurred when participants in the Virtual Reality group completed biceps curls to exhaustion, had significantly lower pain and effort, and exhibited a longer time to exhaustion compared to the control group.[11] After one minute, the VR group reported an average of ten percent lower pain intensity.

To the best of our knowledge, no research has been conducted to experimentally induce pain in athletes, with Capsaicin, to examine how a high degree of immersion or flow using VR can reduce the pain experienced. The purpose of the study was to investigate how pain from Capsaicin, immersion and flow ratings were affected by two Virtual Reality and one computer-based conditions on Canadian baseball athletes. The specific objectives and hypotheses are detailed at the end of the literature review.

Background

What is Virtual Reality?

In 2015, Sports Illustrated named VR the Innovation of the Year.[12] Virtual Reality is a booming industry where programmers are able to create and replicate real-world experiences. The Meta Quest 2 and 3 capture 3D representations of real movements and head direction changes in real time to update the user's viewpoints, while the sensors track the path of the controller or bat, offering users a realistic video projection. Virtual Reality and head-mounted displays (HMDs), like Meta Quest 2, are becoming more affordable, realistic, and portable.

There are many types of immersion, such as Augmented Reality, Mixed Reality and Virtual Reality, where Virtual Reality is the most immersive, due to its complete isolation from the physical world.[13] Fully immersive head-mounted displays provide vivid visualizations, allowing for cognitive, psychomotor, and affective skill development. As a rehabilitation tool, virtual applications could offer individualization, increased compliance, and simulated game scenarios that can be infinitely replicated.[13,14]

An industry that is already valued at 60 billion dollars, the VR segment in healthcare is expected to multiply in the coming years.[1] Compared to conventional rehabilitation or no intervention at all, VR conditions yielded significantly better results for improving balance, rehab from spinal cord injuries, burn victims, and stroke patients.[1]

Recent Studies using VR

Over the last year, we have seen a lot of research published using VR technology for a wide range of issues. In a 2023 study, Gilmour and colleagues explored the effects of a painful thermal stimulus on drinking behavior within a VR bar environment.[15] Twenty participants were exposed to two conditions: painful heat (44°C) and non-noxious warmth (38°C), both applied to the calf to ensure free movement and maintain the immersion of the VR setup. The findings indicated that men, but not women, drank more rapidly under painful conditions, as evidenced by a significant decrease in sip interval. Furthermore, the study called for future research to consider using a topical Capsaicin application to intensify the heat pain stimulus.

Another 2023 study by Lemmens and von Münchhausen examined how game difficulty in VR affected the sense of flow during a rhythm game called Beat Saber.[16] The study revealed that players experienced higher levels of flow when the game's difficulty matched their skill level, compared to when it was too hard. High difficulty led to increased frustration, negatively impacting flow. Interestingly, gameplay that was too easy did not significantly increase boredom or decrease flow. The findings emphasize the importance of balancing game difficulty with player skill to optimize engagement and enjoyment in VR games. This insight is critical for designing VR applications in healthcare, where sustained motivation and performance are essential for therapeutic success.

In a 2024 pilot study, Saby and colleagues assessed a novel VR-based digital therapy for chronic pain in the lower back or upper extremity.[17] Twenty-four patients conducted eight biweekly virtual embodiment (immersion) training sessions over four weeks. Using the HTC Vive VR system (similar to Meta Quest 2), participants engaged in graded motor imagery exercises, including laterality training, motor imagery, mirroring, and predictive coding. Pain intensity was measured before and after each session using a visual analog scale (VAS) and the study found significant reductions in pain intensity ($p < 0.001$), suggesting that immersive VR rehabilitation exercises could be used as a safe and effective nonpharmacological treatment for chronic pain in the general population.

Current uses of Virtual Reality in Sports

Fully immersive VR has been shown to be effective in healthy athletes, mainly as a training tool.[9,18,19] The capability to create specific and reproducible environments in virtual spaces makes VR ideal for preparing and training athletes. For example, VR was effective in reducing perceived anxiety levels for female athletes before a soccer match.[20]

In a scoping 2023 review, athletes were assessed for predispositions to getting injured by using augmented and Virtual Reality, in conjunction with laboratory cameras and facilities.[21] VR and AR were used to place the athletes in 3D simulations to closely resemble their sport in a laboratory setting and try to find abnormalities and prevent injuries via biomechanical analysis.

While these references are a good start, the majority of the limited published research using VR in sports rehab has focused on Football (American Soccer). A major gap in the literature exists for research on post-acute sports injuries and using VR to reduce pain and encourage rehabilitation in ball sports athletes. Additionally, as noted by Stafford and colleagues last year, "there is a lack of information available on how clinical staff in elite sporting organizations can use this technology effectively".[22]

For example, some athletic therapy clinics and professional athletes, such as the former Los Angeles Dodgers Corey Seager and A.J Pollock, have begun to publicly describe their use of Virtual Reality in rehabilitation.[23–25] This increase in use, however, doesn't appear to be evidence based. As a result, there is a lack of research and consensus on best practices. The

University of Alabama Athletic Training staff had the idea in 2016 to use the devices the football team were already using for film practice, as a rehabilitation tool. The staff were candid; "although we weren't entirely sure how to implement it, we understood that putting our injured athletes into a different environment would benefit their recoveries."[25] Exposing athletes, coaches and health care professionals to the mechanisms and the "why" Virtual Reality works is important. Many coaches and health care professionals have anecdotally seen the value in VR, but empirical, rigorous testing is lacking.

What are the psychological dimensions of Virtual Reality?

Immersion is a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences.[26] Immersion in an arcade game is not the same as having your entire field of vision immersed and every interaction being tracked live with you. Immersion is most affected by being fully isolated from your real environment, being self-involved in the virtual environment, with natural forms of interactions, control, and latency. Spiegel states that people may use roughly 50 percent of their brains in visual processing, so when the eyes are bombarded with spectacular and dynamic visions, three billion neuronal firings per second will fire through half the brain to process the overwhelming load of visual data."[1] This level of stimulus is a key part to feeling immersed and transported away from reality.

Both involvement and immersion are necessary for experiencing presence.[26] Involvement can be obtained easily from many forms of media, which do not require fully immersive Virtual Reality. Immersion requires that the participant feel as if their movement and actions in the virtual environment are as close to reality as possible. Fully immersive participants feel that they are directly interacting with the environment, not indirectly or remotely. Immersion is best obtained using fully immersed VR, no form of media compares.[26]

These terms are important because they lead to a concept known as **Flow,** which is one of the most important aspects of our project, attentional analgesia.[4] The experience of flow is described as a narrowing of the perceptual field, an enhanced focus on the task at hand, a feeling of control leading to elation and finally to a loss of self-awareness that sometimes results in a feeling of transcendence, or a merging with the activity and the environment.[27–30] Flow appears to occur most often in settings that are not considered part of “real” everyday life: games, music, sports, rituals, meditative states, and aesthetic experiences. How immersion, flow, and pain interact with each other is of key interest to our study.

Outcome Measures of Flow and Immersion

Psychological Flow Scale (PFS)[31] (see appendix Figure 1)

For more than 40 years, researchers have been studying flow, the psychological state of absorption and effortlessness in one's actions.[31] Csikszentmihalyi's flow model has been criticized for its lack of clear definitions, biased reliability, and uneven application and assessment across fields. The nine-dimensional model is frequently replaced in experimental research by a universal measure (challenge-skill balance), which may not reflect the experience of flow, and is commonly accepted as a precursor to flow rather than an experiential dimension.

The Psychological Flow Scale (PFS) is a psychological diagnostic tool designed to assess flow in individuals who speak English.[31] The PFS is made up of nine items, three for each of the three flow constructs/dimensions: absorption, effort-less control, and intrinsic reward. A scoping review involving over 230 flow-related works across multiple scientific disciplines found that flow was assessed using 141 different measures and described using 108 varying constructs, terms, or dimensions. A common theme that emerged was the use of varied descriptive constructs that contributed to challenges when synthesizing research findings. The study's goal was to construct and give preliminary evidence of the PFS's reliability and validity.

While other scales like Flow State Scale and Dispositional Flow Scales by Jackson and colleagues exist, their limited access (pay for use) and the new PFS (2023) smaller number of questions aligned more closely with our goals for this project. The validation process for the PFS addressed recent conceptual criticisms of flow science and we decided the PFS fit best with our objectives as the PFS only takes a few minutes to fill out on average. Due to time constraints (our study was very long, 1-2 hours per person), we preferred to use a shorter scale.

Immersion Experience Questionnaire (IEQ) [32] (see appendix Figure 2)

The Immersion Experience Questionnaire is a subjective 32 question document that focuses on immersion and presence in games.[32] The 32 questions range from subjective account of levels of enjoyment, to how immersed and "in the game" they feel. For the purposes of our study, we wanted to utilize this questionnaire to decern whether the athletes felt more immersed in the VR game situation when compared to the VR easy batting practice or Two-Back task.

N-Back (Two-Back)[33] Task (see appendix Figure 3)

To gauge working memory and attention, researchers in psychology and neuroscience frequently employ the N-back task.[33] Participants in this activity are shown a series of stimuli, like letters or numbers, one at a time. For this study, we used the two-back task in which participants replied to letters shown on a computer screen in reference to two letters before the current one. The subject must be able to hold many stimuli in memory, refresh their memory with each new stimulus, and pay attention just to the pertinent stimuli while performing the task.

We chose to include this condition because the N-back task has been used extensively for cognitive load and previously researched for distraction with pain.[34,35] We wanted to have a non-VR active control task to show that the Virtual Reality was able to distract more than simply nothing at all. In this way, we can compare three visual and cognitively stimulating conditions, as well as specifically comparing the difficulty levels of VR to each to other.

Simulator Sickness Questionnaire (SSQ)[36] (see appendix Figure 4)

The Simulator Sickness Questionnaire is a brief questionnaire that allows researchers to get subjective data on how the participant felt while in Virtual Reality.[36] Simulator Sickness is a phenomenon where, when a person enters VR, they may become nauseous or dizzy from the device being placed on their head and movements in the virtual space not matching their reality. This phenomenon typically happens more frequently when the VR activity requires running or movement, causing the brain and body to have a disconnect due to the participant not actually moving in the real world. This questionnaire is recommended as a means to provide evidence of an outlier in your experiment and to ascertain if the research was an issue or simply the person was not able to experience the VR properly.

Pain

What is Pain?

Pain is a complex and multifaceted experience that can be defined as unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage."[37] Pain can occur at any moment, and is completely subjective, making it extremely difficult to study.

Pain is an important signal for athletes and clinicians to acknowledge during rehabilitation.[33] Injury, illness, or invasive medical procedures can all result in pain. Pain can be acute, intermittent, or chronic in origin and the economic cost to the healthcare system and society is tremendous.[4-8] As health care professionals, we treat injured patients each day, trying to find the best solutions for our clients to get better. The body has many resources to increase and/or inhibit pain signals that we can utilize.[33]

Mechanisms of Pain

Perception and Processing of Pain

1. **The Stimulus Perception:** Pain perception begins with the detection of unpleasant or possibly harmful stimuli by nociceptors, which are specialised sensory receptors.[33] These receptors are responsive to unpleasant input in a variety of types, including thermal, mechanical, pressure and chemical stimuli.
2. **Transmission of Signal:** When nociceptors are stimulated by noxious stimuli, they produce electrical signals in the form of action potentials.[38] These signals are sent to the central nervous system (CNS) via peripheral nerve fibres (A-delta and C fibres).
3. **Spinal Cord Processing:** When nociceptive signals reach the spinal cord, they are first evaluated.[38] This procedure entails the modulation and integration of pain signals, with some signals enhanced and others suppressed or filtered away.
4. **Ascending Pathways:** Pain signals that are not regulated at the spinal cord level climb to the brain via ascending routes such as the spinothalamic tract.[38] These pathways send pain signals to various brain regions for processing.
5. **Pain Perception in the Brain:** Pain perception happens in several brain areas.[38] The somatosensory cortex plays a role in localising and characterising pain sensations,

supplying information about their position, intensity, and characteristics. Meanwhile, the limbic system, which includes the amygdala and cingulate cortex, influences emotional reactions and coping mechanisms, contributing to the emotional and affective elements of pain.

6. **Modification and Control:** Endogenous pain modulatory mechanisms, such as the release of endorphins and other neuropeptides, can influence pain perception.[38] Furthermore, descending brain circuits can exert inhibitory or facilitative control on pain signals, affecting their intensity and persistence.

Chronic Pain and Memory

7. **Memory and Learning:** Pain experiences are retained in the brain as memories, which aid in adaptive behaviour and future pain avoidance.[38] The ability of the brain to remember painful events aids humans in learning from prior experiences and avoiding potentially dangerous situations.
8. **Chronic Pain:** In chronic pain, maladaptive changes in the neural system can occur, resulting in persistent discomfort even in the absence of continuous tissue damage.[38] These changes can include increased nociceptors sensitivity and changes in pain processing circuits inside the brain.
9. **Psychological elements:** Psychological elements such as emotions, thoughts, and beliefs can have a significant impact on pain perception.[38] Pain perception can be exacerbated by stress, worry, and negative emotions, but good emotions, relaxation techniques, and cognitive tactics can help lessen pain.

How can we induce experimental Pain? [39]

Pain is the most common symptom in clinical practice, and how it affects our treatments is extremely important.[39] How to objectively measure pain has been a difficult task to achieve, but some of the most common methods of experimental pain induction include the cold pressor test, pain prick test, and electrical stimulation.[39] Each of these represent a different category of pain induction; thermal, mechanical and electrical, respectively (see appendix Figure 5). They primarily work by inducing temporal summation, where stimulating the sensors repeatedly increases the signal and results in painful stimulus past a threshold.

Mechanical

The most common methods of mechanical pain induction are touch, pinprick, and pressure.[39] These methods apply a standard amount of pressure repeatedly with a finger, device, or needle. For this study, completing this safely during a baseball activity was not an option, unless we asked the participants to stop, which would take them out of the immersion in VR.

Thermal

For thermal pain induction, applications of cold ice, heat or devices that are capable of reaching high and low temperatures are most common.[39] These methods were considered, however, most thermal pain induction models require the device to be in direct contact with the skin. While this is feasible, the nature of our study does not lend itself to having wires and devices attached to the participants, as the athletes will be swinging and playing baseball (moving a lot). Cold modalities tend to be wet and pose a safety risk from slipping, while heat related modalities require high temperatures with consistent skin contact risking burns.

Electrical

Electrical stimulation via electrodes placed on the body were seriously considered. The method is very appropriate for neurophysiological assessments of pain as they can activate central mechanisms of pain.[39] However, once again, safely implementing this method while playing their sport and attached to electrodes would have been difficult. Additionally, depending on the method of electrical stimulation, muscle fibers may contract during NMES stimulation making it very difficult to swing and increase the potential for injury during testing.

Experimental pain allows for the researcher to focus on the pain they are creating, and limit the confounders present with different conditions. By establishing each participant's individual pain, we were able to track how it changes over the course of the study. As a result, we considered the final category of experimental pain induction: chemical stimulation.

Chemical

Chemical pain induction via Capsaicin and mustard oil are the most common options.[39] Mustard oil has not been tested as much as Capsaicin and for that reason we selected Capsaicin. Both methods cause an inflammation and burning pain at the site of application.

Capsaicin

For this study, we decided to chemically induce experimental pain using Capsaicin. *Capsaicin* is an algogenic (pain producing) chemical, which has been widely used to elicit experimental skin pain, burning and secondary hyperalgesia.[39,40] Capsaicin does not cause any damage or have any potential serious side effects and is safe to use.[41]

In lab-based pain research, Capsaicin is commonly used as a tool to simulate acute pain to study the physiological changes that occur.[40,42–48] Intradermal injection or topical application of Capsaicin evokes similar pain in the skin and the application induces primary and secondary hyperalgesia. Thus, 100 mg of Capsaicin administered intradermally causes a brief burning sensation at the injection site, which is followed by the onset of secondary hyperalgesia. Since similar results can be observed after using a topical lotion containing Capsaicin for 30 to 60 minutes, we have opted for the non-invasive topical option.[39] The 2-3 cm area of subsequent hyperalgesia is identified by brush and pinprick stimulation of the skin around the injury.

C-fibres are believed to primarily mediate the pain that Capsaicin causes. There is typically a significant delay from application to painful stimulus with Capsaicin, often averaging 30-45 minutes. We discovered that preheating the area with a thermal pad, which has been shown to be effective in speeding up the reaction, could reduce the time needed for the study.[49]

Why did we choose to use Capsaicin?

We chose Capsaicin because we needed a pain stimulator that would allow the athletes to be mobile, free, and swinging as already mentioned. Being mobile was also the same reason we chose the Meta Quest 2, even though there are more expensive and different quality VR devices. We wanted to make sure the VR conditions were as realistic as possible for the athletes and health care professionals, who would not typically have access to high end computers and need a device that would be cheap and portable to use on multiple clients.

For the Capsaicin, we were also limited by the availability of the cream. Capsaicin cream, in Canada, is not very common and over the counter options are much lower concentrations then recommended in previous research from the USA. We piloted using Capsaicin cream and oil and found it could induce at least 4/10 pain in testing, which was sufficient for our study. Lastly, we decided to use experimental pain instead of real injuries because examining injured people might interfere with their treatment, which would not be ethical.

The Impact of Pain on Attention

Pain seizes and demands your attention and forces you to protect yourself.[50] Human attention spans are quite short[6] and the brain can be manipulated to prioritize, become overwhelmed, or be distracted from these signals.[34] As a result, the individual has less mental capacity to interpret pain receptor impulses when immersed in something like Virtual Reality. Attentional capture occurs because pain is essential for survival throughout evolution.[33,40] When the brain detects a painful stimulus, the brain prioritises pain, directing attention away from other ongoing processes. [28]

Pain Models

The Limited Resource Model of Attention: Proposed by Kahneman in 1973, the limited resource model of attention asserts that individuals possess a fixed capacity for processing information and engaging in cognitive activities.[6] This model clarifies the limitations within which our cognitive system operates, emphasizing that our bodies have a finite capacity to receive signals and allocate attention. Consequently, in the face of multiple stimuli, various inputs must compete for attention, a phenomenon that can give rise to task-related hypo-analgesia. Patients therefore express less pain while immersed, and spend less time contemplating their discomfort.[4,7,51] Additionally, participants frequently express higher enjoyment during wound care while in VR as compared to wound care without VR.

The Motivation-Decision Model: The motivation-decision model posits that when subjects are more motivated to accomplish a task, pain can be inhibited more significantly by directed attention.[34] The assumption being that baseball athletes will be more motivated during conditions related to their sport, increasing their amount of flow and immersion and thus task-related analgesia and motivation.

Gap in the Literature and Significance of the Research

These fundamental models of pain inhibition have been explored by other researchers, but, to our knowledge, no research has used these theories together to test the combined effects of motivation and task demands on pain and task performance by having sport specific conditions and various difficulties of baseball tasks. Additionally, based on the recent 2023 systematic review by Norsworthy and colleagues, this study would be the first to examine flow from the discipline and perspective of an Exercise Scientist, with focus on baseball athletes.

Quantifying the state of flow is very difficult. We chose to focus on flow and immersion specifically in the questionnaires we selected, as we are not psychologists, and these two measures are the most influenced by a fully immersive environment like VR. Virtual environments, specifically when using a head-mounted display, provide the best experience and isolation for engaging immersion and flow.[26] There are a wide range of methods professionals use for helping their clients be immersed, however, no one method is proven to work for everyone. Distraction techniques, such as deep breathing, listening to soothing music, and watching a favorite video are often used for pain reduction.

VR has the capability to immerse the participant in a virtual world and help them forget or distract them from their pain.[4] While athletes have been training with VR[23], to the best of our knowledge, no research has been conducted on how VR distraction affects Canadian athletes pain ratings. One challenge of rehabilitation for baseball and softball players is replicating the on-field experiences and training psychological and oculomotor aspects are rarely included in typical rehabilitation protocols. From the moment of injury until returning to play, rehabilitation will look very different based on many factors such as the setting, the practitioner, and the level of the athlete, to name a few. Severe injuries with long-term rehab often neglect sport specific exercises until ROM and strength can be minimally regained. In contrast, when nearing a full recovery from injury, health care professionals will begin to implement sports specific training to ensure a safe return to play for the athlete. This is often done in collaboration with the coaching staff or strength and conditioning coordinators of the team.

Our brain rewires itself to remake connections that were lost or damaged during injury.[52] Neural plasticity could be a factor in the success of Virtual Reality for rehabilitation of injuries. Neural plasticity is described as the nervous system's capacity to reorganize its structure, functions, or connections in response to internal or external stimuli. Virtual Reality can provide multisensory feedbacks that can assist the use-dependent plasticity processes within the sensory-motor cortex, thus promoting functional motor recovery.[19] The sensorimotor control systems most affected by VR are the vestibular, visual and oculomotor, cervical neuromotor control training, movement coordination, and postural/balance.

Many articles cited the need for a theoretical framework of Virtual Reality application to sport, and randomized control studies, as opposed to the common one group pre/post intervention.[53] Most research has been completed on chronic disease, hospital settings, endurance sports training and more emphasis on skill-based ball sports is needed. Previous studies have mostly observed clinical pain, while few have looked at healthy individuals or athletes.[54] The affordability of Virtual Reality devices has been noted as a possible limitation as to why smaller university, high school and local teams have not bought into to the technology.[55] Promisingly, the cost of these devices have significantly declined in just the last few years, and devices like the Meta Quest 2, priced at $299 are a significant reason for selecting this Head-Mounted Device for our research. In contrast to common athletic training room tools like a Game Ready cooling device ($3000+), Norma Tec compression recovery ($1000+), and one

Rogue Fitness Squat Rack ($1500+), Virtual Reality devices are versatile, relatively inexpensive and rehabilitate many aspects of recovery for therapy clinics to easily implement. Should VR prove to be efficient in reducing pain for athletes, engaging and immersive, VR will be another tool health care professionals can use at an accessible price point.

Aim

The aim of this study was to investigate whether sport-specific Virtual Reality, in the form of hitting baseballs in a virtual environment, can reduce chemically induced pain in baseball players. This is why we decided on three conditions, to compare a computer based and cognitively engaging task to different Virtual Reality conditions. By allowing each participant to conduct all three conditions, we aim to closely track pain rating subjectivity and variability by using each participant as their own control.

Hypotheses

1- Pain will be significantly reduced during the Hard and Easy VR tasks compared to the N-back test.

2- Pain will be reduced more during the Hard VR task compared to the Easy VR task and N-Back Task.

3- Athletes will have increased flow and immersion during the Hard VR task compared to the Easy VR task and N-back task.

Design

The study was a repeated measure, within-subject design, with all participants completing a one-day, three-condition experiment. The three conditions each participant completed were 1) a two-back task, 2) an easy VR batting practice, and 3) a hard VR simulated game task, completed in a random order, as generated by a randomizer software to ensure the order of the tasks were not a limitation. Participants had a thermal pad warm the calf area for ten minutes, followed by chemically induced pain using 3 ml of Capsaicin cream applied to the calf of the back stance leg during a baseball swing. Pain ratings using a numerical rating scale (NRS) were collected from the beginning of application every minute until the participant reached the same rating of 4+/10 for three consecutive minutes. Once reached, NRS ratings were collected from the start of each condition until the end of the three ten-minute conditions. Capsaicin has been shown to be an effective method of producing experimental pain that can be tracked over the course of an experiment**.**[39]

Outcome Measures:

We drew on their pre- and post-induced pain data to compare the effectiveness of the conditions in reducing pain. The primary outcome measurement was the difference in NRS pain ratings between the Easy and Hard sport-specific Virtual Reality and the Two-Back task during the three conditions. Secondary outcome measures included differences in flow and immersion scores on the IEQ, PFS and SSQ questionnaires. Then, we conducted correlational analysis between immersion and flow with pain ratings.

Ethical Considerations, Confidentiality, Clinical Trial Registry and Funding

Ethical clearance and patient consent were obtained from the Concordia University Ethics Board. Inducing pain needs to be completed in a careful manner. Research inducing pain with Capsaicin leaves no damage to the skin post conditions, or causes any adverse reactions, thus while the cream can be uncomfortable and painful, the study was deemed safe.[39] Each participant was randomly assigned a code for confidentiality and this research was partially funded by MITACS.

Population, Sample and Participant Characteristics

Participants were recruited from Concordia and McGill Universities and local Montreal baseball teams. The participants were healthy athletes aged 18 to 35 years. They were required to have at least two years of baseball experience. Athletes who wear glasses to see properly (contact lenses were accepted or those who just use glasses for reading and have good vision), had a current injury, could not tolerate baseline temperature, did not feel pain during the trials, had severe motion sickness, diagnosed systematic disease, or had altered sensations in their extremities were excluded. In addition, participants were excluded if they were currently in pain, taking pain medication (NSAIDs, Tylenol, Advil, etc.) or had a skin condition that affects the skin barrier (eczema and similar dermal conditions, excessively dry, cracked skin and fresh scars). Capsaicin is not recommended on open wounds or conditions that affect the skin barrier.

Each participant filled out a standard health history form. We then orally reviewed the inclusion and exclusion criteria with the participants before they agreed to participate in the study upon arrival on data collection day. We then had them fill out a standard demographic questionnaire (See appendix Figure 6). Overall, we had 30 participants come into the lab. One participant moved away from Montreal and did not finish the study. Three participants left the study as soon as pain was not reached and did not complete the study. Therefore, a total of 26 participants completed the study. However, nine participants never reached 4+/10 pain and were excluded from the pain analysis but were included in the immersion and flow analyses. A total of 17 participants reached pain of 4/10 and were included in the pain analysis.

	Total	Mean	Max/Min
Age (years)		21.7	33/18
Years of Baseball Experience (years)		15	28/6
Baseball Level	University = 22 Local = 4		
Previous Experience with VR	Yes = 10 No = 16		
Previous Experience with Capsaicin	Yes = 0 No = 26		

Table 1: Key demographic information from all participants who completed the study

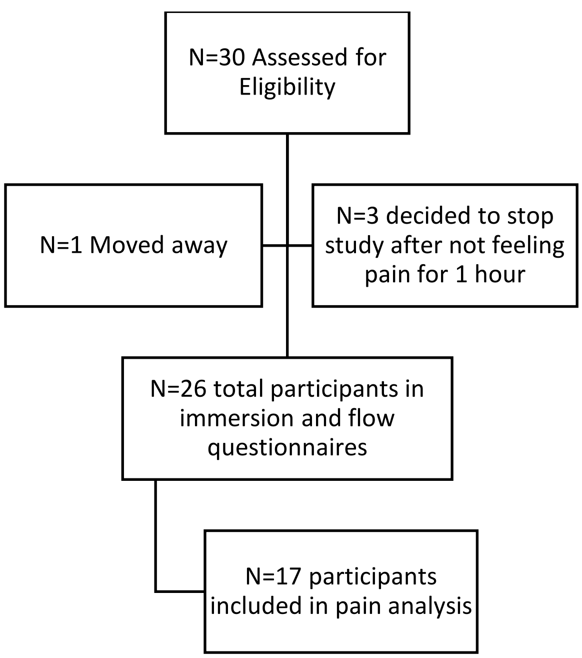


Figure 1- Flow diagram of participants who were included and excluded from the study

Study Setting and Duration

The study took place at the Concordia University Athletic Therapy Lab. We conducted the study from August 2023 until March 2024.

Instructions for Participants (24 hours prior to testing)

Participants were instructed to avoid drinking or consuming stimulants, including but not limited to, coffee, tea, soft drinks, or energy drinks. If medication had to be taken on a regular schedule, prescribed medication was allowed before the assessment. As some medications or drugs could influence pain ratings, if the medication could have been taken after the baseline measurement, we encouraged participants to do so. Participants avoided the use of ointments on their legs (creams, oil, skin lotions, etc.), cosmetics (e.g., makeup, deodorant, antiperspirants, talc, etc.), and medicated ointments (analgesic, vasodilators, cold gel, spray, etc.) prior to assessments, as these products could have reacted with the cream.

Participants were asked to avoid the use of heat or cold modalities twenty-four hours prior to the study to avoid creating a physiological effect on the skin surface temperature.[56] Heat modality included heat packs, electrical heating pad, therapeutic ultrasound, and electrotherapy.[56] Cold modality includes ice packs, ice baths, or frozen gel pack.[56] Participants were asked to bring shorts and athletic attire for testing, but this was not required to participate.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics version 29.0, with an alpha level of 0.05 set for determining statistical significance. Prior to the main analyses, assumptions of normality, sphericity, and homogeneity of variances were tested. Corrections were applied where necessary, including the Greenhouse-Geisser correction for violations of sphericity. A paired sample T-Test was conducted to check the change in pain from start to finish and ensure the capsaicin cream did not simply wear off over time. We compared the mean pain ratings using a one-way repeated-measures ANOVA. We used the Tukey HSD post-hoc pairwise comparisons to explore specific differences between conditions. We then conducted a 2x3 repeated measures

ANOVA to analyze the average pain ratings. After finding a significant interaction, we ran two one-way ANOVAs to determine the mean differences for average and minimum pain experienced but found no significance, and decided it was not worth completed post hoc analysis by hand to find a small interaction. To analyze the immersion scores on the IEQ we conducted a one-way ANOVA followed by a Tukey post-hoc test. We did the same analysis for flow scores with the PFS global, absorption, effortless control and intrinsic reward, respectively. To assess the participants experiences with each condition's difficulty we conducted a one-way ANOVA and Tukey post-hoc test. To assess the impact of time on pain ratings we conducted a repeated measures ANOVA and correlational analyses (Pearson and Spearman tests). To assess the Simulator Sickness means between participants who experienced pain and those who did not, we conducted an independent samples T-test. All significant and non-significant results were reported with appropriate statistics to provide a comprehensive understanding of the findings, ensuring robustness and relevance to the research objectives.

Power analysis with G∗Power 3.1.9.6 for a repeated measures within subjects ANOVA with two groups and three measurements and an assumed medium effect size of $f = 0.25$, and an $\alpha = 0.05$, showed that a total sample size of 28 participants is sufficient to obtain a power of 0.80.

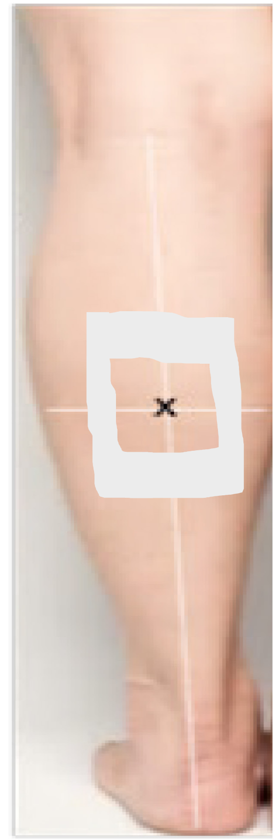
Procedures

Testing

Preheating Period

The pre-heating of the skin has been shown to accelerate the Capsaicin stimulation.[45] The pre-heating allowed us to optimize our time with the participants and accelerate the peak reaction to Capsaicin in participants. To pre-heat the skin, we used a commercial electrical heat pad that is comfortably warm for ten minutes, directly to the back stance leg calf.[49]

Capsaicin Application Period



Once the pre-heating period was completed, we proceeded with the cream application. The researcher applied a non-porous tape on the participant's calf of their back stance leg during a baseball swing, mid belly, with a 2x3cm opening in the middle (see example image to the right). We used medical tape to have a standardized area of cream application for all participants. We utilized a readily available, over-the-counter topical Capsaicin cream with a concentration of 0.05%. Capsaicin is the same ingredient that causes spicy peppers to be hot. Each participant received a small quantity of 3 mL of the Capsaicin cream, which was applied topically with a tongue depressor and medical gloves. All participants had the same Capsaicin cream application.

Pain ratings

The Numerical Rating Scale (NRS) is the gold standard for pain rating assessment and was used in this study to ensure the participant could stay immersed in the task while providing ratings of their pain (see appendix Figure 7).[57] The choice to select the NRS and not the Visual Analog Scale (VAS) was intentional, to ensure immersion and flow were not jeopardized while taking pain ratings. The researcher simply needed verbal confirmation of pain ratings instead of the participant needing to take the VR headset off to look at the VAS scale and select a number, thereby removing themselves from the VR immersion.

The researcher began tracking the participants pain ratings each minute following the Capsaicin application. The researcher asked the participant to rate their pain from 0-10 and marked this down. Participants were told that 10/10 pain "is the worst pain imaginable" and 0/10 pain means "no pain or sensation at all". Pain fluctuated over the course of the trials and randomization was implemented to ensure the order in which the trials or the cessation of painful stimulation were not confounders.

This period ended when the participant mentioned the pain was at a 4/10 or higher for three consecutive minutes. This rating was chosen because 4/10 is a moderate painful level according to the NRS and three minutes allows the pain ratings to stabilize, in our piloting. Should the pain ratings be higher than 4/10 but not the exact same for three consecutive minutes, this period continued until there was three minutes of the same exact value above 4/10. For clarity, if a participant rated 4/10, 4/10, and 5/10 consecutively, this period would continue until they would rate 5/10, 5/10, 5/10 or any other value above 4/10 consecutively.

If the participants requested to stop at any point, or if the pain disappeared to 0/10 for three subsequent minutes prior to beginning the three conditions, testing would be stopped. There was normally a delay of around 30-60 minutes to reach peak pain intensity. The total time for testing was approximately one-to-two hours in length, due to the delay of 30-60 minutes for presentation of symptoms from the Capsaicin and the conditions to be completed.

Virtual Reality Meta Quest 2 Procedure

When ready, the researcher placed the Meta Quest 2 on the participant's head. The guardian (safety area) was created and ensured a safe distance from any object or person. The Win Reality Application was loaded with a live broadcasting to the researcher's computer, phone, or tablet via the Meta Quest app or website. The virtual environment had been designed to simulate a baseball field, and the participant only engaged in hitting, no pitching or fielding drills. The researcher instructed the participant to begin the practice or game by driving the bat through the virtual “Start” button to begin. Participants were allowed to try the application for up to three minutes, if they had no VR experience, to attenuate themselves and act as a tutorial to ensure even greater safety. If they had previous VR experience, they were given the option.

The order in which the participants completed the three conditions were randomly assigned by Excel random order generator. At the completion of each condition, we measured the level of immersion (IEQ) and flow (PFS) using the questionnaires provided. Each participant was instructed to respond to the questionnaires for the condition they had just completed, and not all conditions prior. At the completion of all three tasks, regardless of which was last, the participant completed the Simulator Sickness Questionnaire (SSQ). For the SSQ, the participant was instructed to respond with respect to the VR conditions only, not the Two-Back.

Figure 8: This image was taken of a baseball athlete ready to engage in the study

Condition Periods randomized to 1-2-3, 1-3-2, 2-3-1, 2-1-3, 3-2-1, 3-1-2

The three conditions to be completed were a Two-Back Task, an easy batting practice Virtual Reality simulation and a hard game Virtual Reality simulation for a total of around 30 minutes, ten minutes each.

Below is a description of the three conditions:

1. N-Back (Two-Back) Task

For the Two-Back task, we used the program by Psytoolkit (https://www.psytoolkit.org/experiment-library/touch_nback2.html). On a computer screen, letters were displayed one at a time as the stimuli. For this study, we set the N-back task to two. Thus, when the current stimulus matched the letter that appeared two stimuli ago, they were told to react (hence the name "two-back"), by pressing the "M" button to indicate if the stimulus being presented now matched. For instance, the participant should press "M" when the second "C" lettered appeared since it matched the "C" that appeared two stimuli ago if the sequence of stimuli was "X C A C Q". If the letter was not the same, they did nothing. There was one practice round and then two rounds of data collection. We collected a pain rating before starting the trial run as a baseline. No data was collected during the trial run and the researcher did not interact with the participant to mimic the timeframe in VR conditions where the participant was left alone to be immersed. Once ready, pain ratings were taken at the beginning, 15th response (mid-way point) and after each trial. After each block of trials, participants were automatically given visual feedback on their accuracy and response time by the computer program. The participant was instructed to continue to the next trial when they were ready. At the end of condition, we collected a pain rating, flow (PFS) and immersion scores (IEQ) via the questionnaires. After completion of the questionnaires, we collected another final pain rating. The total time for the two-back was approximately ten minutes.

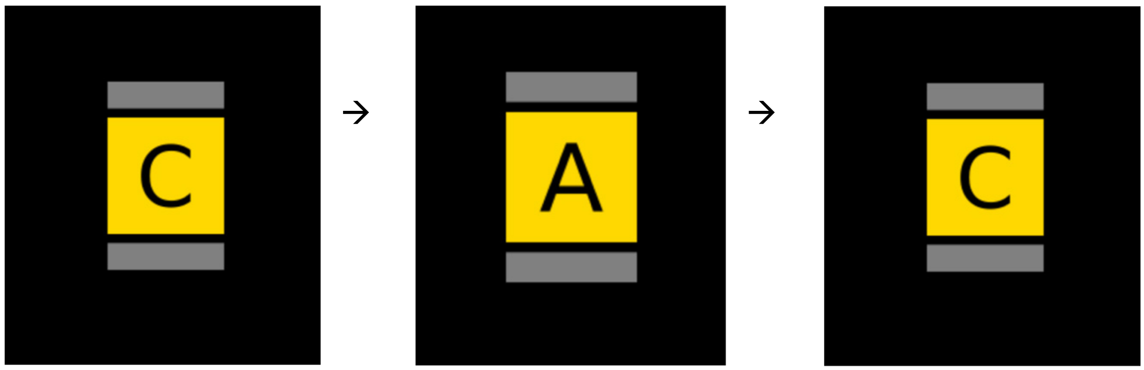


Figure 9: An example of the letters displayed on screen in the Two-Back task

2. Easy Batting Practice VR

For the Easy VR condition, the same right-handed pitcher named Riggs Wasquez was selected for all participants from the Win Reality library. The average mph of pitchers aged 18-40 in Canadian Baseball is around 80 mph, so to make the practice easy, the pitcher threw no faster than 70 mph and we selected for him to only throw fastballs in the strike zone. In addition to the slower pitching, the field was also reduced to represent a little league field as opposed to a regular baseball field with no crowd. Pain ratings were collected before the start, at the start once the headset was on, at the five-minute mark (mid-way) and each minute after, until the end of the 10-minute condition. At the end of each trial, we collected a pain rating once they took the VR headset off, flow and immersion scores via the questionnaires, and a pain rating score once completed.

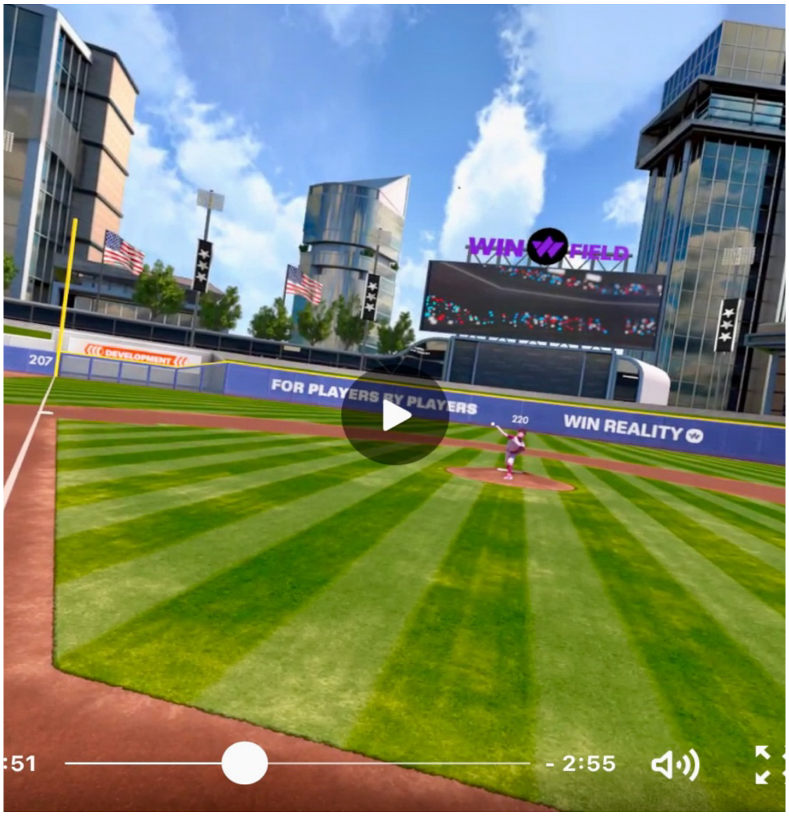


Figure 10: These images were taken from the VR easy practice condition video

3. Hard Simulated Game VR

For the Hard VR condition, the pitcher was named Douglas Mcintosh for all participants and threw strikes and balls via fastball, curveballs, sinkers, sliders randomly, emulating a real game situation. The pitcher threw around 85 mph to really challenge the participants. The application randomly created scenarios for the hitters to challenge the participants in game-like situations and the crowd reacted. For example, a runner on first and second base will appear at the beginning of the at bat with one out, and the objective will be displayed, such as, “Hit the ball to the right side of the field and score the runners in a game”. Pain ratings were collected before the start, at the start, at the five-minute mark (mid-way) and each minute after, until the end of the 10-minute condition. At the end of each trial, we collected a pain rating once they took the VR headset off, flow and immersion scores via the questionnaires, and a pain rating score once completed. We also collected the simulator sickness (SSQ) information following the end of the three trials (whichever was the last condition).

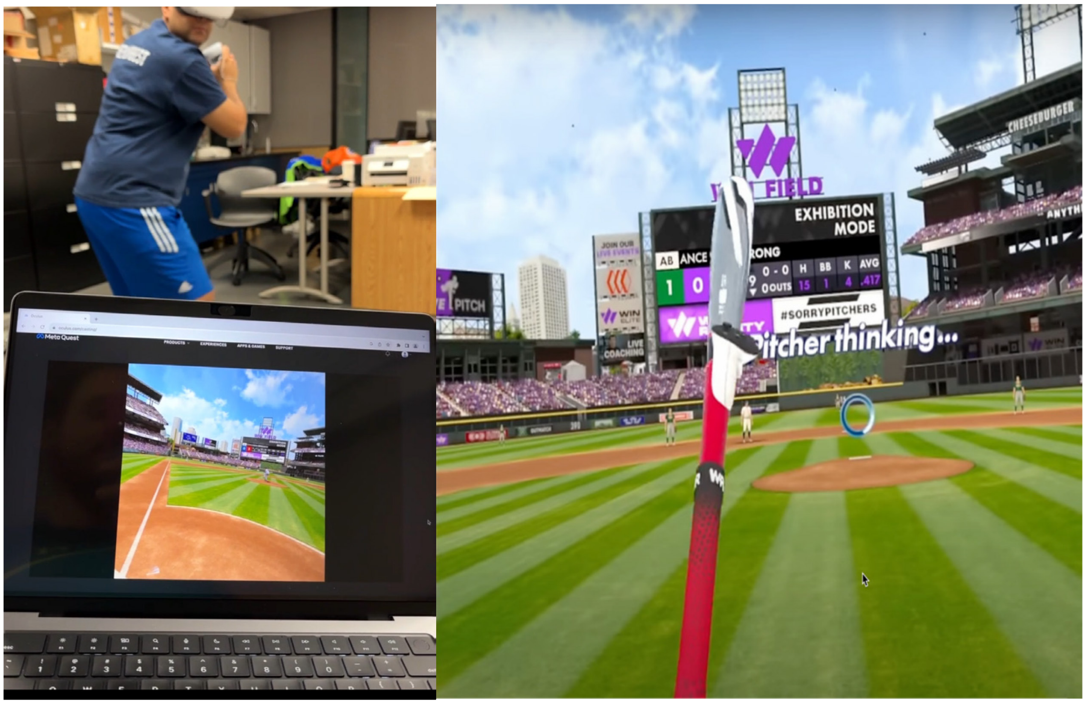


Figure 11: These images were taken of a baseball athlete ready to engage in the HardVR

Questionnaires

In a pain study using Virtual Reality, there were a variety of questionnaires that could be used to gauge flow and immersion.[58–60] For the purposes of our study, and the focus of our research, we decided to utilize the new **Psychological Flow Scale (PFS)**[31] to collect flow ratings, and the Immersive Experience Questionnaire (IEQ) for immersion ratings during the VR conditions, as outlines earlier.

Psychological Flow Scale (PFS) (See Appendix) [31]

The PFS has nine items that assess the flow experience.[31] Items 1-3 assess the dimension ‘absorption’. Items 4-6 assess the dimension ‘effort-less control’. Items 7-9 assess the dimension ‘intrinsic reward’. For reporting purposes, the scores for both global and each of the three dimensions are recommended.

Immersive Experience Questionnaire (IEQ) (See Appendix) [32]

The Immersive Experience Questionnaire (IEQ) is designed to measure the subjective experience of immersion in virtual environments via 32 questions. The IEQ specifically focuses on gaming and how the participant feels during the game. One thing we particularly liked for our study is the last question, which is a direct, single measure of immersion to get a general sense of how immersed they felt. Additionally, Questions 6, 8, 9, 10, 18 and 20 are negative questions which allows for a more in-depth and accurate analysis. The IEQ was developed by the Interaction Centre at University College London. Since the IEQ is a longer questionnaire, approximately five minutes was allocated.

The Simulator Sickness Questionnaire (SSQ) (See Appendix) [36]

The SSQ is a 16-item survey that assesses the participant's level of simulator sickness. It measures factors such as nausea, dizziness, and disorientation and helps guide the researcher should a participant’s scores or ratings be drastically different than expected. This data is important to collect because the results may be affected should a participant have any severe symptoms, and the study itself may not be the issue. The researcher may use this information to exclude them post completion. The total time to complete the SSQ is around two minutes.

Study Completion

Upon completion of the study, we implemented a protocol for the Capsaicin removal. This ensured the participant had no lasting effects from the Capsaicin after completing the study. We first iced the area for five minutes and then sprayed a Briotech cool spray used to neutralize the Capsaicin. The area was then washed with soap and water. After this process, it was unlikely the participant would feel any effects of the Capsaicin again. To be safe, we repeated this step once more for precaution and instructed them to ice the area should they feel any sensations following their departure and contact us at any time. We were not contacted.

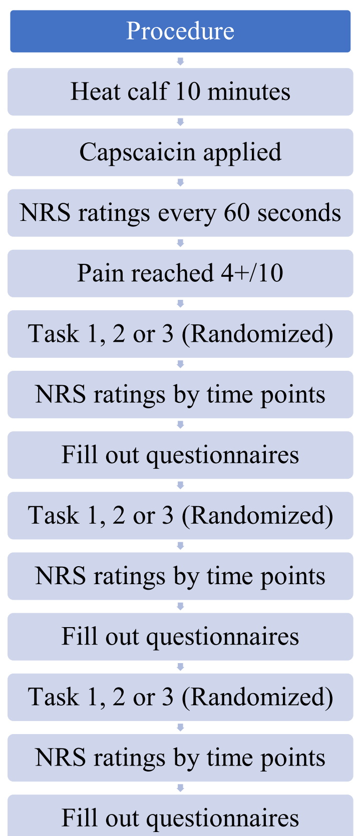


Figure 2. Flow Diagram timeline for baseball players to participate in the conditions during Capsaicin-induced pain. Each participant conducted all three conditions, in a computer-randomized order following the heating period and Capsaicin application.

Results

We induced pain using Capsaicin and then evaluated three conditions to assess their pain reduction capability. Therefore, checking to see if the pain induction from the Capsaicin decreased over time was important. To check this, we used a paired sample t-test to compare the pain before the start of the three conditions and one at the end after they completed the last questionnaire (SSQ). There was no statistically significant change in pain from the beginning of the testing to the end of the last condition ($t(16) = 2.08$, $p = 0.054$) (see appendix Table 2).

Conditions	Mean Pain (SD)
Pain Before Start of Conditions	4.9 (1.7)
Last Pain Rating after SSQ (end of study)	3.9 (3.0)

Table 2: Mean pain ratings and standard deviations before starting and average of last three pain ratings before starting to the last data point after the SSQ at end of study

We compared the average amount of pain experienced during the Easy VR, Hard VR, and Two-Back conditions using a one-way ANOVA. The ANOVA indicated no significant main effect of condition on pain ratings ($F(2, 48) = 0.67$, $p = 0.52$).

Conditions	N	Mean (SD)	Std. Error	95% Confidence Interval for Mean		Minimum
				Lower Bound	Upper Bound	
Easy VR (1)	17	4.0 (2.6)	0.6	2.7	5.3	0.2
Hard VR (2)	17	3.9 (2.7)	0.7	2.5	5.3	0.1
Two-Back (3)	17	4.9 (2.5)	0.6	3.6	6.2	0.9

Table 3: Mean pain experienced from three conditions during Capsaicin application in participants

We conducted a (2X3) (time before and after, condition x 3) repeated measures ANOVA analyzing how the average pain ratings before starting each condition changed from the average during the conditions for 17 participants. The assumption of sphericity was violated ($p < 0.001$), therefore we used the Greenhouse-Geisser correction. There was a significant time main effect ($F = 6.58$, $p < 0.001$). There was also a significant interaction between time and condition (F =

8.31, p = 0.002), therefore we ran a one-way ANOVA to determine where the mean differences were. The one-way ANOVA was not significant and completing a post-hoc was not necessary to find such small changes (F = 0.531, p = 0.753). Of note: the means were between 4.8 and 3.9 so the change in pain was not clinically significant (a change of 2/10 or more). The results were similar for the minimum pain experienced, the lowest pain rating during each condition. The 2X3 ANOVA indicated a significant time main effect (F = 25.94, p < 0.001) and interaction between time and condition (F = 9.48, p = 0.02). We conducted the same analysis to examine if there was a difference between the pain before starting and the minimum pain experienced, but again found no statistical significance (F = 1.373, p = 0.241).

Time Point	Easy VR Mean (SD)	Hard VR Mean (SD)	Two-Back Mean (SD)	All Conditions
Pain Before Start	4.8 (2.4)	4.7 (2.4)	4.9 (2.5)	4.8
Average Pain During Each Condition	4.0 (2.6)	3.9 (2.7)	4.9 (2.5)	4.3

Table 4: Mean pain ratings before starting and average of pain during each condition for 17 participants

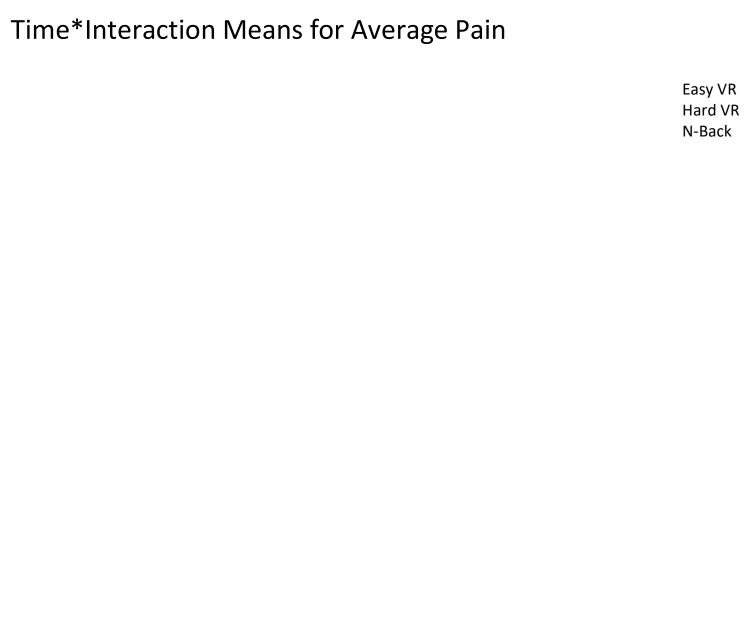


Figure 3: Interaction figure for the mean of average pain compared to before starting each condition

Time Points	Easy VR Mean (SD)	Hard VR Mean (SD)	Two-Back Mean (SD)	All Conditions
Pain Before Start	4.8 (2.4)	4.7 (2.4)	4.9 (2.5)	4.8
Minimum Pain During Each Condition	3.4 (2.7)	3.3 (2.9)	4.5 (2.7)	3.7

Table 5: Repeated measures and one-way ANOVA of before starting condition to minimum pain in each condition.

Time*Interaction Means for Minimum Pain

Easy VR
Hard VR
N-Back

Figure 4: Interaction figure for the mean of minimum pain compared to before starting each condition

Immersion and Flow Results

Significant variations in Immersion Experience Questionnaire (IEQ) total scores between the three groups were identified by the one-way ANOVA ($F(2, 75) = 34.99$, $p < .001$). The Tukey HSD test was used for post hoc comparisons, and the results showed that the mean scores for Easy VR ($p < .001$) and Hard VR ($p < .001$) were statistically significantly higher than the mean scores of the Two-Back, but not between Easy VR and Hard VR themselves ($p = .456$, see appendix Table 6).

Conditions	N	Mean (SD)
EasyVR (Group 1)	26	170.8^^ (19.7)
HardVR (Group 2)	26	178.2^^ (18.3)
Two-Back (Group 3)	26	130.9 (26.8)
^ p = <0.05, ^^ p < 0.01		

Table 6: Mean total scores of the Immersion Experience Questionnaire

The results of the one-way ANOVA for Global PFS, Absorption and Intrinsic Reward scores each revealed statistically significant effects (F (2,75) = 6.659, p = 0.002, F (2,75) = 4.056, p = 0.021, F (2,75) = 20.70, p < 0.001, respectively). The results of the one-way ANOVA for Effortless Control showed no statistically significant difference in PFS Effortless Control scores between the groups (F (2,75) = .609, p = 0.547).

Post hoc comparisons using the Tukey HSD test indicated that the Global PFS mean scores for Easy VR (p = 0.01) and Hard VR (p = 0.004) were statistically significantly higher than the Two-Back (see appendix 7a Table). However, there was no statistically significant difference between Easy VR and Hard VR (p = 0.96).

Conditions	Global Total Score (SD)	Absorption Mean (SD)	Effortless Control Mean (SD)	Intrinsic Reward Mean (SD)
Easy VR (1)	56.0^ (5.4)	6.5 (0.6)	5.7 (1.0)	6.4^^ (0.8)
Hard VR (2)	56.6^^ (5.2)	6.6^ (0.6)	5.7 (1.0)	6.6^^ (0.6)
Two-Back (3)	49.5 (11.1)	6.0 (1.0)	6.0 (1.1)	4.5 (2.0)
^ p = <0.05, ^^ p < 0.01				

SD= Standard deviation, N=26

Table 7: Mean total scores of Psychological Flow Scale (PFS) and subtotal of absorption, effortless control and intrinsic reward for each condition

Post hoc comparisons using the Tukey HSD test indicated that the Absorption mean score for Hard VR (p = 0.028) was statistically significantly higher than the Two-Back (see appendix

7b Table). However, there was no statistically significant difference between Easy VR and Two-Back ($p = 0.065$) or Easy VR and Hard VR ($p = 0.937$). All three conditions showed a higher than normal absorption total score when compared to previous studies with an average score of 5.5 on the PFS. [31]

Post hoc comparisons for intrinsic reward using the Tukey HSD test indicated that the Easy VR ($p < 0.001$) and Hard VR ($p < 0.001$) scored statistically significantly higher than Two-Back condition, but no difference was found between Easy and Hard VR ($p = 0.851$) (see appendix 7c Table). When compared to previous research, we were able to attain a high intrinsic reward score on the PFS for Easy VR and Hard VR when compared to the normal score of 5.8.[31]

Post hoc comparisons using the Tukey HSD test indicated there were no statistically significant differences between any pair of normal effortless control total score when compared to previous studies with an average score of 5.4 on the PFS.[31]

Difficulty of the Conditions

We wanted to check to ensure that the difficulty of each condition was setup appropriately. As part of the IEQ, question 17 asks, “To what extent did you find the game challenging?”. We conducted a one-way ANOVA looking at the results to the responses for this question with respect to each condition. The ANOVA was statistically significant ($F(2,75) = 10.0$, $p < 0.001$) and post hoc Tukey test indicated that Hard VR was statistically significantly harder than the Two-Back ($p = 0.01$) and Easy VR ($p < 0.001$) (see appendix table 8)

Conditions	Mean (SD)
EasyVR	3.9^^ (1.4)
HardVR	5.5 (1.1)
Two-Back	4.4^ (1.4)
^ p = <0.05, ^^ p < 0.01	

Table 8: Mean ratings for difficulty of each condition on the IEQ number 17

Repeated Measures ANOVA and Correlational Analysis

A repeated measures ANOVA for each condition over the ten time points of Easy VR and Hard VR conditions and eight time points for Two-Back was conducted to investigate the impact of time on pain ratings. The sphericity assumption was broken for Easy VR and Hard VR ($F = 5.66$, $p < 0.001$). This means one must use the Greenhouse-Geisser correction, and the main effect of time was significant ($F = 5.66$, $p = 0.003$) and ($F = 5.41$, $p = 0.003$), respectively. For the Two-Back condition, the sphericity assumption was not significant ($F= 0.35$, $p = 0.72$).

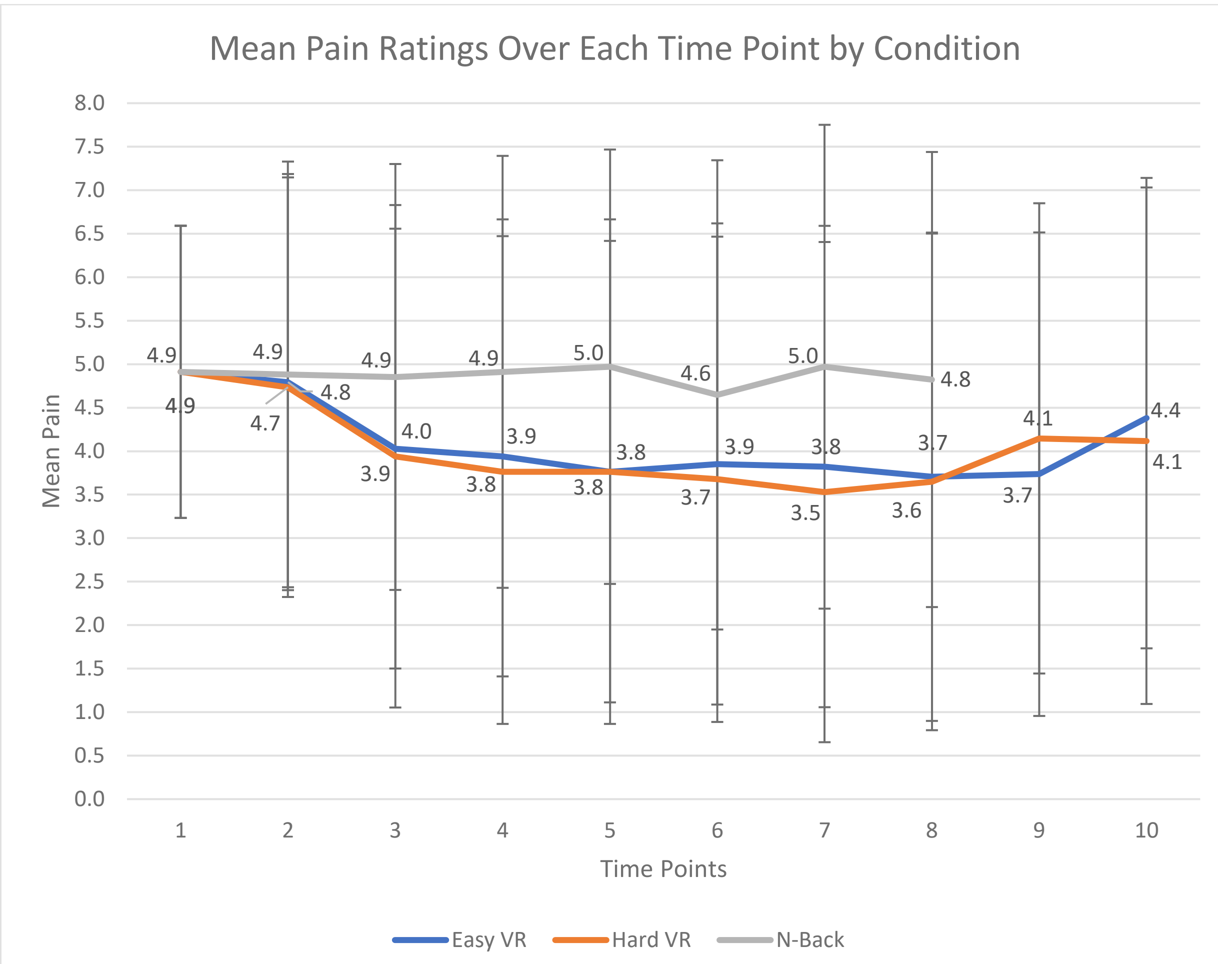


Figure 5: The mean pain ratings for each condition displayed by time point

A Pearson correlation analysis was conducted to examine whether there was a correlation between pain ratings and immersion or pain ratings and flow. An inverse relationship would confirm the hypothesis that the more immersion or flow attained, the lower the pain. The Pearson correlation results found no statistically significant inverse correlation between pain and immersion scores on Easy VR IEQ ($r = 0.055$, $p = 0.835$) or Easy VR PFS ($r = -0.016$, $p = 0.952$), Hard VR IEQ ($r = 0.054$, $p = 0.838$) or PFS Hard VR ($r = -0.035$, $p = 0.893$), or Two-Back IEQ ($r = -0.201$, $p = 0.438$) or Two-Back PFS ($r = -0.190$, $p = 0.465$). Due to small sample size, Spearman correlation analysis was also recommended to be reported but found no statistically significant differences as well (see all correlations in appendix table 11).

Conditions	Mean Pain	Immersion IEQ	Flow PFS
EasyVR	4.0	174.5^^	56.8^^
HardVR	3.9	180.6^^	55.7^^
Two-Back	4.9	121.9	46.6
^ p = <0.05, ^^ p < 0.01			

Table 9: Mean pain ratings, immersion scores and flow scores for each condition for only the participants who felt pain during the study

Simulator Sickness Questionnaire

Virtual Reality causes simulator sickness and we conducted an independent t-test to ensure that whether the participant was in pain from the Capsaicin or not, we would find similar ratings. There were 17 participants who experienced the pain target of 4+/10 to be included, while 9 participants did not and conducted the conditions as well. We transposed the ratings of NONE, Slight, Moderate and Severe to 0, 1, 2, 3, respectively and ran the independent samples test showed that these groups did not reach statistical difference. Levene's test indicated equal variances ($F = 0.13$, $p = 0.72$). The t-test results showed no significant difference in SSQ scores between the groups ($t = 0.22$, $p = 0.83$). We were interested to ensure the groups had similar ratings and less focused on the specific symptoms felt by the participants for this study.

Groups	N	Mean (SD)
Pain	17	0.23 (0.18)
Not Enough Pain	9	0.22 (0.19)

Table 10. Descriptive Statistics of Simulator Sickness Questionnaire for Participants who felt pain and those who did not meet the requirements

Discussion Section

Contrary to previous research, our results showed no statistically significant differences in pain perception across the mean pain ratings for all conditions.[2,54] The initial hypothesis was that VR conditions would lessen pain perception in comparison to cognitive pursuits; however, statistical analysis showed that pain ratings were statistically similar in all scenarios and had no clinical significance. These results imply that in terms of pain reduction, neither VR condition was statistically superior to the Two-Back task. However, these results warrant further exploration based on the literature showing VR is a valid tool to reduce pain ratings. A larger sample size may have found statistical significance as the mean ratings for both VR conditions are lower than the Two-Back which did not see much change.

We used a chemically-induced pain method, which has been shown to be effective at inducing pain.[39] Prior to the study, we piloted using a Capsaicin oil and a cream and decided to select the cream, as they both showed effectiveness and the cream was easier to contain within the 2x3 area during application. However, our first limitation was that in the end, the Capsaicin only triggered a moderate to high level of pain (4+/10) in 17/30 participants, a 57% inclusion rate. This severely limited our sample size and affected the statistical significance of the results. Additionally, one concern with such a lengthy study (the entire study lasted 1-2 hours per person), was whether the Capsaicin cream would wear off over time. Consistent with previous research, the Capsaicin was able to last the duration of the 30-60 minute period, as evidenced from the paired samples t-tests before starting the condition to the last rating following the Simulator Sickness Questionnaire.[39] When looking closely at the maximum pain, the Capsaicin pain induction method for all three conditions had very similar maximum pain rating averages, indicating there was a consistent peak pain experience for participants. Future research that uses similar methodologies should expect to see a similar pattern. Capsaicin with a high concentration is extremely hard to obtain in Canada and if we had access to a higher concentration, we may have seen a higher success rate. Future researchers should investigate their local regulations for concentration, seek a higher percentage and consider using the oil-based Capsaicin.

Pain is extremely subjective, and many participants referred to the sensation of Capsaicin as burning instead of painful which could have influenced their ratings. We considered that based on the subjectivity and complexity of pain, overall mean pain ratings for VR conditions may not display the true effectiveness of VR, as the pain ratings appear to return to pre-condition level once the headset was removed. Thus, we looked at comparing the minimum or lowest value reported when compared to the pre-condition ratings for each group separately and analyze this further. The results indicate that Virtual Reality did not have a statistically significant effect, which again is inconsistent with previous research.[2,54] The brain has a limited ability to prioritize attention to multiple stimuli, known as the limited resource model of attention, which is the major factor in why Virtual Reality reduces pain.[6] VR is able to take attention away from the pain signals being received by the brain, and can have an analgesic effect. We believe that asking the participants each minute during the VR condition may have taken them out of immersion and brought attention to their pain. Additionally, playing the sport of baseball encourages blood flow and players to sweat, which would increase the temperature of the skin and possibly raise the pain experienced by the athlete compared to previous research that was more stationary in nature (for example playing chess seated). This mechanism is the reason we conducted a preheating of the calf prior to starting the application of the cream, so it is possible that playing baseball activated the Capsaicin cream, counteracting the conditions effects of distraction.

We also decided to conduct a repeated measures to look at the specific details of each participant's pain by time points. This was a result of the significant linear and quadratic contrasts indicating that pain ratings decreased during the condition phases, but the effects appear to have worn off after taking the VR headset off and completing the questionnaires, which is expected since the participant would now bring attention back to their pain. In fact, in a few cases, we saw a clinically significant change of 2 or more for individual participants pain dropping during the VR conditions, that wasn't seen in the Two-Back. One participant even reacted during the VR condition, confused as to why they were not feeling the pain from the cream anymore, only to have the pain return immediately upon removing the VR headset and laughing at how incredible and "magical" the experience was. A larger sample size may have displayed this phenomenon more frequently leading to statistically significant differences between the conditions, as seen in previous VR pain research.

Previous research has also shown that being more motivated or immersed in a task is beneficial to inhibit pain, the motivation-decision model we utilized.[61] Our results clearly show a large difference between the mean scores of Easy VR and Hard VR when compared to the Two-Back Task. All three conditions showed a higher than normal overall level of immersion when compared to other research previous average scores of 125 on the IEQ.[62] This suggests that the athletes were not as immersed in the Two-Back when compared to the VR conditions which could have an impact on future directions for engaging athletes in their sport and seeing a greater pain reduction. If a clinician wants to immerse their athlete outside of the field of play, VR would be a good option.

With respect to the Two-Back task, participants were notified if they made the correct or incorrect selection immediately during the task, as well as at the end. This could affect the participants focus and motivation during the task, and future researchers should consider other programs that do not provide feedback during the condition to ensure more consistency in participants experience. The fluctuations in ratings could also reflect varying levels of engagement or distraction provided by the VR tasks, as compared to Two-Back conditions. Full immersion in VR activates more of the senses than a computer-based task and could indicate why the Two-Back tasks, while cognitively demanding, did not provide sufficient distraction or therapeutic effect to impact immersion significantly. These results warrant future use of full-immersion Virtual Reality, as we can see the effect on how immersed a participant felt during the task compared to previous normal scores on the IEQ.[62]

We were surprised to see that the pain ratings were not statistically or clinically significantly different, and the immersion and flow scores for Easy VR and Hard VR were very similar. A possible explanation for this observation is that our Virtual Reality conditions motivated the athletes to compete similarly. The initial goal was for the Easy VR condition to be boring and repetitive resulting in low motivation, immersion, and flow. However, because we needed to use a slower and easier pitcher, the participants completed the Easy VR condition on a smaller little league baseball field, compared to the full-size field simulation in Hard VR. This led to participants consistently trying to hit homeruns for the duration of the condition and motivated them in a different way than the challenges of Hard VR. In a way, this ultimately showed that there are different ways to immerse and engage athletes by offering them a challenge, or a chance to boost their confidence and succeed in the condition, as mentioned in the Lemmens and von Münchhausen study.[16] Calibrating the skill level to the participants is important for proper execution, as some people enjoy being successful at a task and may feel more engaged or immersed. This is one of the main reasons why the researchers who designed the Psychological Flow Scale recommend reporting the three individual constructs of flow to display these intricacies of absorption, intrinsic motivation and effortless control.

As the Psychological Flow Scale is relatively new, previous research utilizing it is limited. Our thorough analysis of results will allow future authors to compare their findings for an athletic population. The creators of the questionnaire have emphasized the importance of reporting both the global score and the individual constructs of the PFS as they represent different information.[31] When compared to previous research, we were able to attain a high global score on the PFS for Easy VR and Hard VR when compared to the normal score of 50. The Two-Back total score was just slightly lower than average.[31] When we separated the scores by dimensions, intrinsic reward showed a difference in the Two-Back, characterised by positive valence and optimal levels of arousal.[31] Intrinsic reward is evident in the activation of midbrain reward structures and during flow, there are increased dopamine production, which would explain much higher levels of intrinsic reward in VR conditions than a computer based Two-Back.

Hypothesis three posited that as the level of immersion and flow increased, we hoped to see a decrease in pain ratings (an inverse relationship). The results of Pearson and Spearman correlation analyses of the data did not support this hypothesis. For all three conditions, Easy VR, Hard VR and Two-Back, there were no significant inverse correlations between pain and immersion or flow ratings. Even though there was a clear statistical difference in total scores on the IEQ and PFS for VR conditions compared to Two-Back, the correlation analyses did not support that there was any correlation between this increase in scores to a decrease in pain ratings. With such a small sample size and a lot of variability as evident by the error bars, these findings are logical. With a larger sample size, these differences may have been more pronounced and statistically significant.

Limitations, Future Directions and Conclusions

Baseball is traditionally a male-dominated sport, especially in Canada, although female teams are increasing. We attempted to recruit both genders, but we were not successful in finding teams over 18 years old to be included. We believe comparing genders and how they handle pain differently would be a valuable study to find similarities and differences among genders and be more generalizable to a larger population. We also recruited university and local level baseball players over the age of 18. Different levels and ages would be valuable to investigate as well.

We decided to collect a pain rating at the start of every condition, to control for pain changes over time. While we did not see a statistically significant change in the pain ratings from start to finish, we believe future researchers should emulate this model to ensure an accurate starting point for pain ratings prior to each condition. Not all participants returned to the same pain rating at the start of each condition, and this also allows researchers to see if the previous condition had a lasting effect or not.

Since we did not design the VR application or Two-Back, our capacity to gather objective data regarding the difficulty of each condition was constrained. Ideally, for baseball, we would have preferred to collect objective statistics such as batting average during the conditions. However, to address this limitation, we collected subjective ratings from participants regarding the perceived difficulty of each condition, thereby ensuring that each condition was appropriately tailored for the study.

The use of sport-specific Virtual Reality as a pain reducing condition is based on the theoretical model of flow and the motivation-decision model. Flow theory suggests that when individuals are fully engaged in an activity that challenges their skills, they can enter a state of flow, which is characterized by high levels of focus, enjoyment, and reduced self-awareness. The theory of this study was that by using a sport-specific virtual environment, baseball players may enter a state of flow and immersion, thereby reducing pain perception. By using a randomized controlled design, the study aimed to minimize potential confounding factors and increase the internal validity of the results. Overall, this study design investigated a more specific use of Virtual Reality in a sport-specific context, which may provide insights into how immersive and engaging conditions can further enhance pain reduction in athletes and be a foundation for future research on athletes.

References

1. Spiegel B. *VRx: How Virtual Therapeutics Will Revolutionize Medicine*. Basic Books; 2020. Accessed March 15, 2023. https://www.goodreads.com/en/book/show/50998982

2. Malloy KM, Milling LS. The effectiveness of virtual reality distraction for pain reduction: A systematic review. *Clinical Psychology Review*. 2010;30(8):1011-1018. doi:10.1016/j.cpr.2010.07.001

3. Burdea G. Virtual Rehabilitation - Benefits and Challenges. *Yearbook of Medical Informatics*. Published online 2003:7.

4. Hoffman HG, Patterson DR, Magula J, et al. Water-friendly virtual reality pain control during wound care. *J Clin Psychol*. 2004;60(2):189-195. doi:10.1002/jclp.10244

5. Barcatta K, Holl E, Battistutta L, van der Meulen M, Rischer KM. When Less Is More: Investigating Factors Influencing the Distraction Effect of Virtual Reality From Pain. *Front Pain Res*. 2022;2:800258. doi:10.3389/fpain.2021.800258

6. Kahneman D. *Attention and Effort*. Prentice-Hall Inc.; 1973.

7. Hoffman HG, Richards TL, Bills AR, et al. Using fMRI to Study the Neural Correlates of Virtual Reality Analgesia. *CNS spectr*. 2006;11(1):45-51. doi:10.1017/S1092852900024202

8. Carter L, River B, Sachs M. Flow in Sport, Exercise, and Performance: A Review with Implications for Future Research. 2013;5(3):17-31.

9. Gray R. Transfer of Training from Virtual to Real Baseball Batting. *Frontiers in Psychology*. 2017;8. Accessed September 27, 2022. https://www.frontiersin.org/articles/10.3389/fpsyg.2017.02183

10. Kóbor I, Gál V, Vidnyánszky Z. Attentional modulation of perceived pain intensity in capsaicin-induced secondary hyperalgesia. *Exp Brain Res*. 2009;195(3):467-472. doi:10.1007/s00221-009-1799-0

11. Matsangidou M, Ang CS, Mauger AR, Intarasirisawat J, Otkhmezuri B, Avraamides MN. Virtual Reality: The Effect of Body Consciousness on the Experience of Exercise. Published online 2018:29.

12. Apstein S. Sports Illustrated's Innovation of the Year: Virtual reality. *Sports Illustrated*. https://www.si.com/sportsperson/2015/12/18/innovation-of-the-year-virtual-reality. 2015. Accessed October 28, 2022.

13. Miles HC, Pop SR, Watt SJ, Lawrence GP, John NW. A review of virtual environments for training in ball sports. *Computers & Graphics*. 2012;36(6):714-726. doi:10.1016/j.cag.2012.04.007

14. Saldana D, Neureither M, Schmiesing A, et al. Applications of Head-Mounted Displays for Virtual Reality in Adult Physical Rehabilitation: A Scoping Review. *Am J Occup Ther*. 2020;74(5):7405205060p1-7405205060p15. doi:10.5014/ajot.2020.041442

15. Gilmour C, Blaes S, Bush NJ, et al. Pain and alcohol consumption in virtual reality. *Experimental and Clinical Psychopharmacology*. 2023;31(2):433-442. doi:10.1037/pha0000602

16. Lemmens JS, Von Münchhausen CF. Let the beat flow: How game difficulty in virtual reality affects flow. *Acta Psychologica*. 2023;232:103812. doi:10.1016/j.actpsy.2022.103812

17. Saby A, Alvarez A, Smolins D, et al. Effects of Embodiment in Virtual Reality for Treatment of Chronic Pain: Pilot Open-Label Study. *JMIR Form Res*. 2024;8:e34162. doi:10.2196/34162

18. Michalski SC, Szpak A, Saredakis D, Ross TJ, Billinghurst M, Loetscher T. Getting your game on: Using virtual reality to improve real table tennis skills. Capio CM, ed. *PLoS ONE*. 2019;14(9):e0222351. doi:10.1371/journal.pone.0222351

19. Reneker JC, Pannell WC, Babl RM, et al. Virtual immersive sensorimotor training (VIST) in collegiate soccer athletes: A quasi-experimental study. *Heliyon*. 2020;6(7):e04527. doi:10.1016/j.heliyon.2020.e04527

20. Harrison K, Potts E, King AC, Braun-Trocchio R. The Effectiveness of Virtual Reality on Anxiety and Performance in Female Soccer Players. *Sports*. 2021;9(12):167. doi:10.3390/sports9120167

21. Soltanabadi S, Minoonejad H, Bayattork M, Seyedahmadi M. Effect of Virtual Reality and Augmented Reality Training for Injury Prevention and Accelerating Rehabilitation of Anterior Cruciate Ligament Injury in Athletes: A Scoping Review. *Asian J Sports Med*. 2023;14(4). doi:10.5812/asjsm-139704

22. Stafford J, Williams N, Johnson A, White D, Craig C. An Evaluation of a Low-Cost Virtual Reality Rehabilitation Tool in an Elite Soccer. Published online 2022.

23. Off The Bench. Corey Seager and A.J. Pollock Used VR for Injury Rehabilitation. 2019. Accessed September 24, 2022. https://www.offthebenchbaseball.com/2019/07/26/corey-seager-and-a-j-pollock-used-vr-for-injury-rehabilitation/

24. Athletic trainer uses technology to help student-athletes heal. *Spectrum News*. Published online September 26, 2022. https://spectrumlocalnews.com/tx/south-texas-el-paso/news/2022/09/26/high-tech-healing

25. Vicknair R, Gsell J, Keith C. Seeing Things Differently: University of Alabama using VR in athlete rehab. Training and Conditioning. 2019. Accessed October 29, 2022. https://training-conditioning.com/article/see-things-differently-d66/

26. Witmer BG, Singer MJ. Measuring Presence in Virtual Environments: A Presence Questionnaire. *Presence*. 1998;7(3):225-240. doi:10.1162/105474698565686

27. Csikszentmihalyi M. Finding flow. *Psychology Today*. 2007;(Finding Flow):7.

28. Csikszentmihalyi M. FLOW: The Psychology of Optimal Experience. Published online 2000:6.

29. Csikszentmihalyi M. INTRINSIC REWARDS AND EMERGENT MOTIVATION. In: Greene D, ed. *The Hidden Costs of Reward*. 0 ed. Psychology Press; 2015:223-234. doi:10.4324/9781315666983-19

30. Seligman MEP, Csikszentmihalyi M. Positive psychology: An introduction. *American Psychologist*. 2000;55(1):5-14. doi:10.1037/0003-066X.55.1.5

31. Norsworthy C, Dimmock JA, Miller DJ, Krause A, Jackson B. Psychological Flow Scale (PFS): Development and Preliminary Validation of a New Flow Instrument that Measures the Core Experience of Flow to Reflect Recent Conceptual Advancements. *Int J Appl Posit Psychol*. Published online April 19, 2023. doi:10.1007/s41042-023-00092-8

32. Jennett C, Cox AL, Cairns P, et al. Measuring and defining the experience of immersion in games. *International Journal of Human-Computer Studies*. 2008;66(9):641-661. doi:10.1016/j.ijhcs.2008.04.004

33. Tabry V, Vogel TA, Lussier M, et al. Inter-individual predictors of pain inhibition during performance of a competing cognitive task. *Sci Rep*. 2020;10(1):21785. doi:10.1038/s41598-020-78653-z

34. Vogel TA, Falk CF, Otto AR, Roy M. Distraction from pain depends on task demands and motivation. *PR9*. 2022;7(6):e1041. doi:10.1097/PR9.0000000000001041

35. Gajewski PD, Hanisch E, Falkenstein M, Thönes S, Wascher E. What Does the n-Back Task Measure as We Get Older? Relations Between Working-Memory Measures and Other Cognitive Functions Across the Lifespan. *Front Psychol*. 2018;9:2208. doi:10.3389/fpsyg.2018.02208

36. Balk SA, Bertola MA, Inman VW. Simulator Sickness Questionnaire: Twenty Years Later. In: *Proceedings of the 7th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design : Driving Assessment 2013*. University of Iowa; 2013:257-263. doi:10.17077/drivingassessment.1498

37. Raja SN, Carr DB, Cohen M, et al. The revised International Association for the Study of Pain definition of pain: concepts, challenges, and compromises. *Pain*. 2020;161(9):1976-1982. doi:10.1097/j.pain.0000000000001939

38. Aguggia M. Neurophysiology of pain. *Neurological Sciences*. 2003;24(2):s57-s60. doi:10.1007/s100720300042

39. Staahl C, Drewes AM. Experimental Human Pain Models: A Review of Standardised Methods for Preclinical Testing of Analgesics. *Pharmacol Toxicol*. 2004;95(3):97-111. doi:10.1111/j.1742-7843.2004.950301.x

40. Meeker TJ, Schmid A, Liu Y, et al. During capsaicin-induced central sensitization, brush allodynia is associated with baseline warmth sensitivity, whereas mechanical hyperalgesia is associated with painful mechanical sensibility, anxiety and somatization. *Eur J Pain*. 2021;25(9):1971-1993. doi:10.1002/ejp.1815

41. Stephens DP, Charkoudian N, Benevento JM, Johnson JM, Saumet JL. The influence of topical capsaicin on the local thermal control of skin blood flow in humans. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*. 2001;281(3):R894-R901. doi:10.1152/ajpregu.2001.281.3.R894

42. Fulton BA, Burton EF, Nance S, Letzen JE, Campbell CM. Experimenter- and Infrared Thermography–Derived Measures of Capsaicin-Induced Neurogenic Flare Among Non-Hispanic White and Black Adults. *Pain Medicine*. 2020;21(10):2262-2270. doi:10.1093/pm/pnaa006

43. Serra J, Campero M, Ochoa J. Flare and Hyperalgesia After Intradermal Capsaicin Injection in Human Skin. *Journal of Neurophysiology*. 1998;80(6):2801-2810. doi:10.1152/jn.1998.80.6.2801

44. Pressman A, McCauley L, Edwards R, Haythornthwaite J, Campbell C. Endogenous opioid function mediates the relationship between pain catastrophizing and capsaicin pain in healthy participants. *The Journal of Pain*. 2016;17(4):S57. doi:10.1016/j.jpain.2016.01.233

45. Linde LD, Srbely JZ. The Acute Effect of Skin Preheating on Capsaicin-Induced Central Sensitization in Humans. *Pain Practice*. 2019;19(8):811-820. doi:10.1111/papr.12811

46. Linde LD, Bent LR, Dickey JP, Kumbhare DA, Srbely JZ. Exploring the effect of capsaicin-induced central sensitization on the upper limb nociceptive withdrawal reflex threshold. *Exp Brain Res*. 2021;239(11):3405-3415. doi:10.1007/s00221-021-06216-3

47. Enax-Krumova EK, Pohl S, Westermann A, Maier C. Ipsilateral and contralateral sensory changes in healthy subjects after experimentally induced concomitant sensitization and hypoesthesia. *BMC Neurol*. 2017;17(1):60. doi:10.1186/s12883-017-0839-9

48. Pressman AJ, Peterlin BL, Tompkins DA, et al. Pain catastrophizing may moderate the association between pain and secondary hyperalgesia. *J Appl Behav Res*. 2017;22(1):e12096. doi:10.1111/jabr.12096

49. Nielsen TA. The effect of topical capsaicin-induced sensitization on heat-evoked cutaneous vasomotor responses. *Int J Physiol Pathophysiol Pharmacol*. 2013;5(3):148-160.

50. Eccleston C. Role of psychology in pain management. *British Journal of Anaesthesia*. 2001;87(1):144-152. doi:10.1093/bja/87.1.144

51. Hoffman HG, Richards TL, Coda B, et al. Modulation of thermal pain-related brain activity with virtual reality: evidence from fMRI: *NeuroReport*. 2004;15(8):1245-1248. doi:10.1097/01.wnr.0000127826.73576.91

52. Berlucchi G, Buchtel HA. Neuronal plasticity: historical roots and evolution of meaning. *Exp Brain Res*. 2009;192(3):307-319. doi:10.1007/s00221-008-1611-6

53. Neumann DL, Moffitt RL, Thomas PR, et al. A systematic review of the application of interactive virtual reality to sport. *Virtual Reality*. 2018;22(3):183-198. doi:10.1007/s10055-017-0320-5

54. Demeter N, Josman N, Eisenberg E, Pud D. Who can benefit from virtual reality to reduce experimental pain? A crossover study in healthy subjects. *Eur J Pain*. 2015;19(10):1467-1475. doi:10.1002/ejp.678

55. Lindsay Ross-Stewart, Jeffrey Price, Daniel Jackson, Christopher Hawkins. A Preliminary Investigation into the Use of an Imagery Assisted Virtual Reality Intervention in Sport. *JSS*. 2018;6(1). doi:10.17265/2332-7839/2018.01.003

56. Fernández-Cuevas I, Bouzas Marins JC, Arnáiz Lastras J, et al. Classification of factors influencing the use of infrared thermography in humans: A review. *Infrared Physics & Technology*. 2015;71:28-55. doi:10.1016/j.infrared.2015.02.007

57. Jensen MP. The validity and reliability of pain measures in adults with cancer. *The Journal of Pain*. 2003;4(1):2-21. doi:10.1054/jpai.2003.1

58. Jackson SA, Eklund RC. Assessing Flow in Physical Activity: The Flow State Scale–2 and Dispositional Flow Scale–2. *Journal of Sport and Exercise Psychology*. 2002;24(2):133-150. doi:10.1123/jsep.24.2.133

59. Witmer BG, Jerome CJ, Singer MJ. The Factor Structure of the Presence Questionnaire. *Presence: Teleoperators & Virtual Environments*. 2005;14(3):298-312. doi:10.1162/105474605323384654

60. Lessiter J, Freeman J, Keogh E, Davidoff J. A Cross-Media Presence Questionnaire: The ITC-Sense of Presence Inventory. *Presence: Teleoperators & Virtual Environments*. 2001;10(3):282-297. doi:10.1162/105474601300343612

61. Vogel TA, Falk CF, Otto AR, Roy M. Distraction from pain depends on task demands and motivation. *PR9*. 2022;7(6):e1041. doi:10.1097/PR9.0000000000001041

62. Ruthvik C. *Measurement of Game Immersion through Subjective Approach*. Master's. Blekinge Institute of Technology; 2017.

63. Roy M, Shohamy D, Daw N, Jepma M, Wimmer GE, Wager TD. Representation of aversive prediction errors in the human periaqueductal gray. *Nat Neurosci*. 2014;17(11):1607-1612. doi:10.1038/nn.3832

Appendices

Figure 1- PFS Questionnaire [31]

Psychological Flow Scale (PFS)

The below questions relate to the thoughts and feelings you may have experienced while taking part in your recent activity. There are no right or wrong answers. Think about how you felt during the event/activity, then answer the questions using the rating scale.

Please rate the questions below in relation to the most intense optimal moment you experienced in your given event.

		Strongly disagree	Neutral					Strongly agree
1	I was absorbed in the act/task	1	2	3	4	5	6	7
2	I was highly focused on the task/activity	1	2	3	4	5	6	7
3	All my attention was on the task/activity	1	2	3	4	5	6	7
4	I felt like I could easily control what I was doing	1	2	3	4	5	6	7
5	My actions flowed effortlessly	1	2	3	4	5	6	7
6	There was a sense of fluidity to my actions	1	2	3	4	5	6	7
7	I found the experience rewarding	1	2	3	4	5	6	7
8	The experience felt satisfying	1	2	3	4	5	6	7
9	I would like the feeling of that experience again	1	2	3	4	5	6	7

Figure 2 – Immersion Experience Questionnaire (IEQ) [26]

IEQ

Your Experience of the Game: Please answer the following questions by circling the relevant number (1-7). In particular, remember that these questions are asking you about how you felt at the end of the game.

1. To what extent did the game hold your attention?
   Not at all 1 2 3 4 5 6 7 *A lot*
2. To what extent did you feel you were focused on the game?
   Not at all 1 2 3 4 5 6 7 *A lot*
3. How much effort did you put into playing the game?
   Very little 1 2 3 4 5 6 7 *A lot*
4. Did you feel that you were trying you best?
   Not at all 1 2 3 4 5 6 7 *Very much so*
5. To what extent did you lose track of time, e.g. did the game absorb your attention so that you were not bored?
   Not at all 1 2 3 4 5 6 7 *A lot*
6. To what extent did you feel consciously aware of being in the real world whilst playing?
   Not at all 1 2 3 4 5 6 7 *Very much so*
7. To what extent did you forget about your everyday concerns?
   Not at all 1 2 3 4 5 6 7 *A lot*
8. To what extent were you aware of yourself in your surroundings?
   Not at all 1 2 3 4 5 6 7 *Very aware*
9. To what extent did you notice events taking place around you?
   Not at all 1 2 3 4 5 6 7 *A lot*
10. Did you feel the urge at any point to stop playing and see what was happening around you?
    Not at all 1 2 3 4 5 6 7 *Very much so*
11. To what extent did you feel that you were interacting with the game environment?
    Not at all 1 2 3 4 5 6 7 *Very much so*
12. To what extent did you feel as though you were separated from your real-world environment?
    Not at all 1 2 3 4 5 6 7 *Very much so*
13. To what extent did you feel that the game was something fun you were experiencing, rather than a task you were just doing?
    Not at all 1 2 3 4 5 6 7 *Very much so*
14. 14. To what extent was your sense of being in the game environment stronger than your sense of being in the real world?
    Not at all 1 2 3 4 5 6 7 *Very much so*
15. At any point did you find yourself become so involved that you were unaware you were even using controls, e.g. it was effortless?
    Not at all 1 2 3 4 5 6 7 *Very much so*
16. To what extent did you feel as though you were moving through the game according to your own will?
    Not at all 1 2 3 4 5 6 7 *Very much so*
17. To what extent did you find the game challenging?
    Not at all 1 2 3 4 5 6 7 *Very difficult*
18. Were there any times during the game in which you just wanted to give up?
    Not at all 1 2 3 4 5 6 7 *A lot*
19. To what extent did you feel motivated while playing?
    Not at all 1 2 3 4 5 6 7 *A lot*
20. To what extent did you find the game easy?
    Not at all 1 2 3 4 5 6 7 *Very much so*
21. To what extent did you feel like you were making progress towards the end of the game?
    Not at all 1 2 3 4 5 6 7 *A lot*
22. How well do you think you performed in the game?
    Very poor 1 2 3 4 5 6 7 *Very well*
23. To what extent did you feel emotionally attached to the game?
    Not at all 1 2 3 4 5 6 7 *Very much so*
24. To what extent were you interested in seeing how the game's events would progress?
    Not at all 1 2 3 4 5 6 7 *A lot*
25. How much did you want to "win" the game?
    Not at all 1 2 3 4 5 6 7 *Very much so*
26. Were you in suspense about whether or not you would do well in the game?
    Not at all 1 2 3 4 5 6 7 *Very much so*
27. At any point did you find yourself become so involved that you wanted to speak to the game directly?
    Not at all 1 2 3 4 5 6 7 *Very much so*
28. To what extent did you enjoy the graphics and the imagery?
    Not at all 1 2 3 4 5 6 7 *A lot*
29. How much would you say you enjoyed playing the game?
    Not at all 1 2 3 4 5 6 7 *A lot*
30. When it ended, were you disappointed that the game was over?
    Not at all 1 2 3 4 5 6 7 *Very much so*
31. Would you like to play the game again?
    Definitely no 1 2 3 4 5 6 7 *Definitely yes*

How immersed did you feel? (10 = very immersed; 1 = not at all immersed)

1 2 3 4 5 6 7 8 9 10

Figure 3- Two-Back Task Example [33,63]

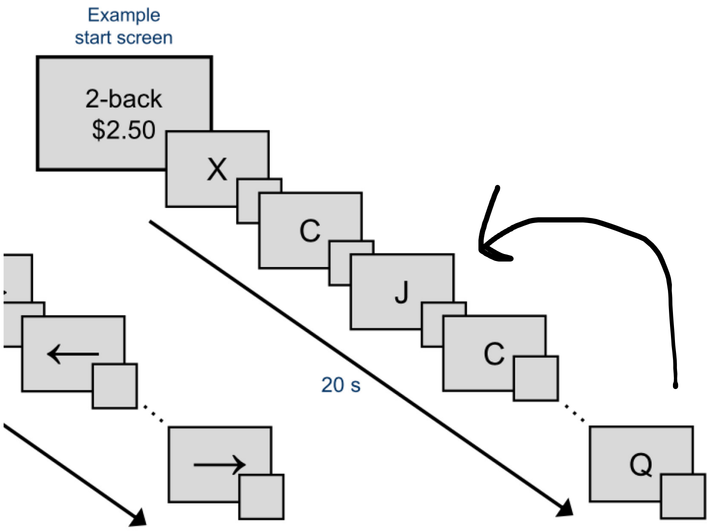


Figure 4- Simulator Sickness Questionnaire (SSQ) [36]

No_____________ Date__________________

SIMULATOR SICKNESS QUESTIONNAIRE
Kennedy, Lane, Berbaum, & Lilienthal (1993)***

Instructions : Circle how much each symptom below is affecting you right now.

1. General discomfort	None	Slight	Moderate	Severe
2. Fatigue	None	Slight	Moderate	Severe
3. Headache	None	Slight	Moderate	Severe
4. Eye strain	None	Slight	Moderate	Severe
5. Difficulty focusing	None	Slight	Moderate	Severe
6. Salivation increasing	None	Slight	Moderate	Severe
7. Sweating	None	Slight	Moderate	Severe
8. Nausea	None	Slight	Moderate	Severe
9. Difficulty concentrating	None	Slight	Moderate	Severe
10. « Fullness of the Head »	None	Slight	Moderate	Severe
11. Blurred vision	None	Slight	Moderate	Severe
12. Dizziness with eyes open	None	Slight	Moderate	Severe
13. Dizziness with eyes closed	None	Slight	Moderate	Severe
14. *Vertigo	None	Slight	Moderate	Severe
15. **Stomach awareness	None	Slight	Moderate	Severe
16. Burping	None	Slight	Moderate	Severe

* Vertigo is experienced as loss of orientation with respect to vertical upright.

** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

Last version : March 2013

***Original version : Kennedy, R.S., Lane, N.E., Berbaum, K.S., & Lilienthal, M.G. (1993). Simulator Sickness Questionnaire: An enhanced method for quantifying simulator sickness. *International Journal of Aviation Psychology, 3*(3), 203-220.

Figure 5- Basic Clin Pharma Tox - 2004 - Staahl - Experimental Human Pain Models : A Review of Standardized Methods for Preclinical.pdf

Table 1.

Examples of different analgesics, which have been used to modify the pain evoked by different experimental pain models of the skin. The table is not intended as a complete list, but to give examples of different drugs, which attenuate experimental skin pain.

Modality	Stimulus	Analgesic substance
Mechanical	Touch	LA
	Pinprick	LA, clonidine, epinephrine, remifentanil
	Pressure	LA, opioids, clonidine
Thermal	Cold	LA, clonidine
	Ice water	Neostigmine
	Freeze lesion	Diclofenac, remifentanil
	Warm	LA, opioids
	Heat	LA, opioids, lamotrigine, ketamine, dextromorphan
	Laser	LA, opioids
	Burn-injury	Opioids, gabapentin
Electrical	Single stimuli	LA, opioids, clonidine
	Repeated stimuli	Ketamine, remifentanil
Chemical	Capsaicin	Clonidine, gabapentin, lamotrigine
	Mustard oil	Adenosine

LA: Local anaesthetics.

Figure 6- Demographic Questionnaire

Demographic Questionnaire

Please take a moment to provide the following information:

Personal Information

- Name (last, first): ____________________
- Best way to reach you (phone # or email): ____________________

Background Information

- Age: ____________________
- Sex: ____________________
- Gender: ____________________
- Race/Ethnicity: ____________________

Physical Characteristics

- Weight (in kilograms): ____________________
- Height (in meters): ____________________
- BMI (automatically calculated): ____________________

Health Information

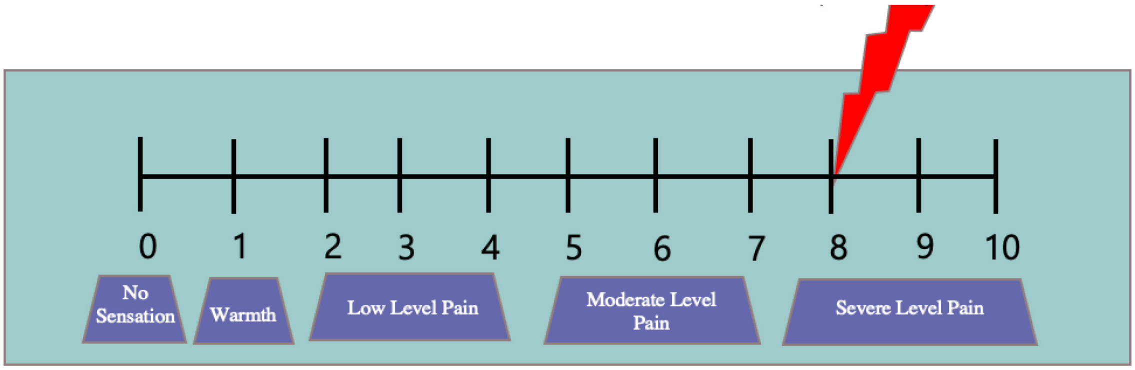
- Allergies/medical conditions: ____________________
- Current pain or injury status: ____________________
- Presence of diagnosed systemic diseases: ____________________
- Presence of altered sensations in extremities: ____________________
- Do you wear glasses? (Yes / No)
- Do you wear contact lenses? (Yes / No)
- Do you currently use any pain medication? (Yes / No)
- Do you experience severe motion sickness? (Yes / No)

Previous Experiences

- How many years of baseball experience do you have? ____________________
- Have you had any previous experience with virtual reality? (Yes / No)
- Have you had any previous experience with capsaicin? (Yes / No)

Privacy Statement: All information provided in this questionnaire will be kept strictly confidential and used solely for research purposes. Your anonymity will be maintained throughout the study.

Figure 7- Numerical Rating Scale (NRS) 5,33,63



Paired Sample T-Test of Pain_StartofConditions vs LastPainRating_AfterSSQ

	Paired Differences					t	df	Significance	
	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
				Lower	Upper			One-Sided p	Two-Sided p
Pain_Startof Conditions - LastPainRating_ AfterSSQ	1.06	2.10	.51	-.02	2.14	2.08	16	.027	.054

Post-hoc comparison of IEQ total scores

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Easy VR	2	-7.30769	6.07801	.456	-21.8409	7.2255
	3	39.92308***	6.07801	<.001***	25.3899	54.4563
Hard VR	1	7.30769	6.07801	.456	-7.2255	21.8409
	3	47.23077***	6.07801	<.001***	32.6976	61.7640
Two-Back	1	-39.92308***	6.07801	<.001***	-54.4563	-25.3899
	2	-47.23077***	6.07801	<.001***	-61.7640	-32.6976

*. The mean difference is significant at the 0.05 level. ** p<0.01 *** p<0.001

PFS Global Scores: Post Hoc Comparisons (Tukey HSD)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Easy VR	2	-.61538	2.13632	.955	-5.7236	4.4928
	3	6.42308*	2.13632	.010*	1.3149	11.5313
Hard VR	1	.61538	2.13632	.955	-4.4928	5.7236
	3	7.03846**	2.13632	.004**	1.9303	12.1466
Two-Back	1	-6.42308*	2.13632	.010*	-11.5313	-1.3149
	2	-7.03846**	2.13632	.004**	-12.1466	-1.9303
*. The mean difference is significant at the 0.05 level. ** p<0.01 *** p<0.001						

PFS Absorption Scores: Post Hoc Comparisons (Tukey HSD)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Easy VR	2	-.07265	.21205	.937	-.5797	.4344
	3	.48291	.21205	.065	-.0241	.9899
Hard VR	1	.07265	.21205	.937	-.4344	.5797
	3	.55556*	.21205	.028*	.0485	1.0626
Two-Back	1	-.48291	.21205	.065	-.9899	.0241
	2	-.55556*	.21205	.028*	-1.0626	-.0485
*. The mean difference is significant at the 0.05 level. ** p<0.01 *** p<0.001						

PFS Intrinsic Reward Scores: Post Hoc Comparisons (Tukey HSD)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Easy VR	2	-.19231	.35441	.851	-1.0397	.6551
	3	1.87179***	.35441	<.001***	1.0244	2.7192
Hard VR	1	.19231	.35441	.851	-.6551	1.0397
	3	2.06410***	.35441	<.001***	1.2167	2.9115
Two-Back	1	-1.87179***	.35441	<.001***	-2.7192	-1.0244
	2	-2.06410***	.35441	<.001***	-2.9115	-1.2167
*. The mean difference is significant at the 0.05 level. ** p<0.01 *** p<0.001						

PFS Effortless Control Scores: Post Hoc Comparisons (Tukey HSD)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Easy VR	2	.02564	.28934	.996	-.6662	.7175
	3	-.26282	.28934	.637	-.9547	.4290
	1	-.02564	.28934	.996	-.7175	.6662

Hard VR	3	-.28846	.28934	.581	-.9803	.4034
Two-Back	1	.26282	.28934	.637	-.4290	.9547
	2	.28846	.28934	.581	-.4034	.9803

Tukey HSD for IEQ 17 for difficulty of each condition

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Easy VR	2	-1.61538*	.36976	<.001	-2.4995	-.7312
	3	-.50000	.36976	.371	-1.3841	.3841
Hard VR	1	1.61538*	.36976	<.001	.7312	2.4995
	3	1.11538*	.36976	.010	.2312	1.9995
Two-Back	1	.50000	.36976	.371	-.3841	1.3841
	2	-1.11538*	.36976	.010	-1.9995	-.2312
*. The mean difference is significant at the 0.05 level.						

Pearson Correlation for Means of AVG Pain, IEQ Total and PFS Total Scores for each condition

		AVGPain During_ EasyVR	AVGPain During_ HardVR	AVGPain During_ Two-Back	IEQTotal Score_ EasyVR	PFS_ Global TotalScore _EasyVR
AVGPainDuring _EasyVR	Pearson Correlation	1	.941**	.938**	.055	-.016
	Sig. (2-tailed)		<.001	<.001	.835	.952
	N	17	17	17	17	17
AVGPainDuring _HardVR	Pearson Correlation	.941**	1	.927**	.120	-.026
	Sig. (2-tailed)	<.001		<.001	.645	.920
	N	17	17	17	17	17
AVGPainDuring _Two-Back	Pearson Correlation	.938**	.927**	1	.091	-.029
	Sig. (2-tailed)	<.001	<.001		.728	.913
	N	17	17	17	17	17
IEQTotalScore_ EasyVR	Pearson Correlation	.055	.120	.091	1	.398

	Sig. (2-tailed)	.835	.645	.728		.114
	N	17	17	17	17	17

		AVGPain During_ EasyVR	AVGPain During_ HardVR	AVGPain During_ Two-Back	IEQTotal Score_ EasyVR	PFS_ Global TotalScore _EasyVR
PFS_GlobalTotal Score_EasyVR	Pearson Correlation	-.016	-.026	-.029	.398	1
	Sig. (2-tailed)	.952	.920	.913	.114	
	N	17	17	17	17	17
IEQTotalScore_ HardVR	Pearson Correlation	-.013	.054	.079	.935**	.315
	Sig. (2-tailed)	.961	.838	.764	<.001	.218
	N	17	17	17	17	17
PFS_GlobalTotal Score_HardVR	Pearson Correlation	-.010	-.035	.028	.259	.856**
	Sig. (2-tailed)	.971	.893	.914	.316	<.001
	N	17	17	17	17	17
IEQTotalScore_ Two-Back	Pearson Correlation	-.158	-.069	-.201	.399	.403
	Sig. (2-tailed)	.546	.792	.438	.113	.109
	N	17	17	17	17	17
PFS_GlobalTotal Score_Two-Back	Pearson Correlation	-.188	-.163	-.190	-.059	.256
	Sig. (2-tailed)	.471	.531	.465	.822	.321
	N	17	17	17	17	17

		PFS_Global TotalScore_ EasyVR	IEQTotal Score_ HardVR	PFS_Global TotalScore_ HardVR	IEQTotalS core_ Two-Back	PFS_ Global Total Score_ Two-Back
AVGPainDuring _EasyVR	Pearson Correlation	-.016	-.013	-.010	-.158	-.188
	Sig. (2-tailed)	.952	.961	.971	.546	.471
	N	17	17	17	17	17
AVGPainDuring _HardVR	Pearson Correlation	-.026	.054	-.035	-.069	-.163

	Sig. (2-tailed)	.920	.838	.893	.792	.531
	N	17	17	17	17	17
AVGPainDuring_Two-Back	Pearson Correlation	-.029	.079	.028	-.201	-.190
	Sig. (2-tailed)	.913	.764	.914	.438	.465
	N	17	17	17	17	17
IEQTotalScore_EasyVR	Pearson Correlation	.398	.935**	.259	.399	-.059
	Sig. (2-tailed)	.114	<.001	.316	.113	.822
	N	17	17	17	17	17
		PFS_Global TotalScore_ EasyVR	IEQTotal Score_ HardVR	PFS_Global TotalScore_ HardVR	IEQTotalS core_ Two-Back	PFS_ Global Total Score_ Two-Back
PFS_GlobalTotal Score_EasyVR	Pearson Correlation	1	.315	.856**	.403	.256
	Sig. (2-tailed)		.218	<.001	.109	.321
	N	17	17	17	17	17
IEQTotalScore_HardVR	Pearson Correlation	.315	1	.269	.363	-.054
	Sig. (2-tailed)	.218		.296	.152	.836
	N	17	17	17	17	17
PFS_GlobalTotal Score_HardVR	Pearson Correlation	.856**	.269	1	.167	.228
	Sig. (2-tailed)	<.001	.296		.522	.380
	N	17	17	17	17	17
IEQTotalScore_Two-Back	Pearson Correlation	.403	.363	.167	1	.667**
	Sig. (2-tailed)	.109	.152	.522		.003
	N	17	17	17	17	17
PFS_GlobalTotal Score_Two-Back	Pearson Correlation	.256	-.054	.228	.667**	1
	Sig. (2-tailed)	.321	.836	.380	.003	
	N	17	17	17	17	17

Comparing the change or Difference from Low to High Pain during EasyVR, HardVR, Two-Back

A one-way ANOVA was conducted to compare the lowest pain rating to the highest by calculating the change. The ANOVA results showed no statistically significant difference between the groups ($F(2, 48) = 2.94$, $p = 0.06$). Post hoc comparisons using Tukey HSD indicated that the mean difference between Hard VR and Two-Back approached significance ($p = 0.07$), suggesting a trend worth further exploration but no statistical significance was found.

Descriptive Statistics for Difference from Low to High Pain Scores by Group

Condition	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum
					Lower Bound	Upper Bound	
Easy VR (1)	17	-1.60	1.10	.26621	-2.1591	-1.0304	-3.50
Hard VR (2)	17	-1.77	1.31	.31831	-2.4395	-1.0899	-4.50
Two-Back (3)	17	-0.85	1.07	.25997	-1.4040	-.3018	-4.00

Participant Data sheet

VIRTUAL-REALITY - EASY	
Time (Min.)	**Pain Rating (0-10)**
Before Starting	
5	
6	
7	
8	
9	
10	
After Finishing	
QUESTIONNAIRES: PFS & IEQ	
Period	**Pain Rating (0-10)**
After Completion	

VIRTUAL REALITY - HARD	
Time (Min.)	**Pain Rating (0-10)**
Before Starting	
5	
6	
7	
8	
9	
10	
After Finishing	
QUESTIONNAIRES: PFS & IEQ	
Period	**Pain Rating (0-10)**
After Completion	

TWO-BACK TASK	
ROUND 1	
Period	**Pain Rating (0-10)**
Before Starting	
At 15th Response	
After Finishing	
ROUND 2	
Period	**Pain Rating (0-10)**
Before Starting	
At 15th Response	
After Finishing	
QUESTIONNAIRES: PFS & IEQ	
Period	**Pain Rating (0-10)**
After Completion	

QUESTIONNAIRES: Simulator Sickness	
Period	**Pain Rating (0-10)**
After Completion	

NOTES