Usability of Virtual Reality for Suprascapular Nerve Block Procedure Training

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I certify that this work does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

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ABSTRACT

Training can be a complex and expensive investment in most industries, however when you consider the added risks associated with training in the medical field these costs become even greater.

Trainees practicing on real patients comes with issues related to the risk of mistakes and patient confidence in their care. Due to the potential risks to the patient, trainees are also unable to be allowed to make mistakes and have the chance to fix them themselves.

Virtual reality is a technology that has been seeing increasing interest from several industries including aviation, oil and gas, medicine, automotive, tourism, law enforcement, real estate, education, and entertainment. This typically takes the form of simulations and serious games, where gamification aspects are used to interest and entice the user, but the core goal of the program is not entertainment.

This project was designed to examine the use of virtual reality in medical training and how it can help to develop the skills of the users without causing risks to the patients or users.

The procedure for a suprascapular nerve block was chosen after consultation with Professor Michael Shanahan, a Professor of Musculoskeletal Rheumatology Medicine who has also authored several papers on suprascapular nerve blocks. This is a procedure that is used to manage chronic shoulder pain in patients and is not easily learnt without the use of real-life patients. The incorrect performance of this procedure can reduce its effectiveness and cause harm to patients.

To achieve risk free training a virtual reality program was developed for use with the Oculus Quest 2. This program was then tested by doctors to evaluate what benefits virtual reality training can bring to the medical industry. To ensure that users would be interested in using the program a usability evaluation was performed to see what its System Usability Scale (SUS) score would be. A total of eleven participants were recruited and provided ratings for the SUS as well as feedback on any difficulties that they faced during the virtual training.

Overall users found the program interesting and rated it 76.65 on the SUS scale, meaning that they considered it to be good in terms of usability. This score and the additional feedback received showed a strong interest in the possibilities of virtual reality medical training.

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INTRODUCTION

Training is highly important across all areas of industry as it is critical for both the development of new skills and the maintenance of current skills (Noe 2019). This can be considerably expensive however, with US companies spending an average of US$1,111 per employee on training in 2020 (Training Industry Inc 2020). Some forms of training can also be difficult or impractical to perform due to limitations such as remote access or the requirement for specific conditions (Visser, Watson et al. 2011).

These complications with training have led to an increase in interest in forms of digital training including augmented and virtual reality (Arntz, Keßler et al. 2020). Oil and gas, medicine, aviation, automotive, tourism, law enforcement, real estate, entertainment and education are all industries that have utilised virtual reality and for many of them this is commonly in the form of simulations and serious games (Akhgar 2019). Serious games are programs that use gamification elements such as competition or fun to interest users however the main goal of the program is not entertainment.

Training with virtual reality is particularly useful in high-risk environments, both for those who are participating in the training or those affected by it such as a medical student's patients. As the training takes place in the virtual world any dangers that users must face are not able to cause real physical harm to them, nor will their mistakes cause harm to others. This also removes the difficulty often faced by new doctors of finding patients that are willing to let them perform procedures when they have not done them before (Shanahan 2021). It can also help the doctors themselves build confidence in their abilities and increase their knowledge to reduce the risk of accidents occurring when performing procedures on real patients.

To ensure that users will participate in training and encourage their interest they must be able to use the tools without unnecessary difficulty. This is particularly important with new technology such as virtual reality which many users may not have experienced before.

PROBLEM STATEMENT

Usability is a core part of ensuring that training is effective and performed by students. If training is frustrating for either students or instructors, they will be less inclined to perform the training. The goal of this study is to investigate the usability of virtual reality training for medical training and in particular the suprascapular nerve block procedure. To achieve this a virtual reality training program needed to be designed and built before being tested and evaluated. The primary audience for this evaluation is rheumatology registrars. However, usability of the program will also be evaluated by other associated medical practitioners and some nonmedical practitioners to gather a greater sample size. This study will also look into the feedback from these participants in the study to examine what factors are needed to create a virtual reality training program with high usability.

LITERATURE REVIEW

This project combines several areas of study including medicine, learning, serious games, virtual reality, and usability. Some of the literature investigated links several of these topics together whilst others may only have singular connections to the project.

The procedure itself is of high importance to the project and therefore research has been undertaken into the suprascapular nerve block (SSNB) procedure. The techniques for doing the procedure are needed to correctly build and design the training program so that it matches how the doctors will perform the procedure in real life. The studies showcasing the benefits of the SSNB procedure are used as justification for the importance of training to help more physicians learn the procedure and help their patients. Studies into SSNB's have found it can grant a significant lasting pain reduction in patients and it has consistently been described as a safe and effective method to manage chronic pain and injuries (Wertheim and Rovenstine 1941, Shanahan, Ahern et al. 2003, Shanahan, Shanahan et al. 2012, Adey-Wakeling, Crotty et al. 2017, Laumonerie, Blasco et al. 2019, Shanahan, Glaezter et al. 2020, Terlemez, Ciftci et al. 2020, Shanahan 2021). SSNB procedures also have very few side effects and these are quite minor and short lived when performed properly (Shanahan, Shanahan et al. 2012). However, if performed incorrectly they can lead to additional complications for the patient such as punctured lungs. Training is therefore important, and the possibility is there for this training to be supplemented by virtual reality.

There are two main forms of SSNB's, either direct injections or indirect injections. Direct injections use imaging equipment such as ultrasounds or computerized tomography (CT) scans to help guide the doctor to the nerve where they then inject the solution. Indirect blocks do not use any imaging equipment and instead use anatomical landmarks to locate the area of the nerve and then inject the patient and allow the solution to spread out and cover the nerve after injection. There are benefits to both forms, direct injections are easier for inexperienced doctors to do as they have additional equipment to help guide them to the proper locations. Indirect injections however can be done much faster and at a significantly reduced cost as they do not require additional equipment or staff for imaging (Shanahan 2021). In a 2004 study Shanahan et al. found no statistic difference in pain reduction between indirect or direct nerve blocks (Shanahan, Smith et al. 2004). Neither method had any greater safety for the patient either with the only side effects encountered being some bruising and local pain to the injection site. This is further backed up by an additional study of 1005 nerve blocks in 2012 that found no severe side effects or issues resulting from the nerve blocks (Shanahan, Shanahan et al. 2012). Additionally, the comparisons of the costs of the two procedures have the indirect nerve block costing between a third and a quarter of the price of a direct nerve block. Indirect nerve blocks can be performed with less impact to the patient as well with the lack of imaging equipment allowing for a much faster and simpler procedure (Shanahan 2021).

Remote locations and developing countries often have difficulty getting access to advanced learning due to the difficultly and expense of sending experts and complicated tools to those areas (Shanahan 2021). However, some virtual reality devices are able to operate without the need for external computers or other equipment which allows for easy portability and transport. Whilst some instructions may be required for users, particularly for specialised programs, virtual reality devices are increasingly being designed for the average consumer allowing for an easier understanding of the device.

It is important to ensure that any training done provides benefits to either the students or instructors and ideally both. Care must be taken to avoid pitfalls such as assuming virtual reality training will be effective simply because it is immersive, or students will remember things that they have done. This belief is often based on Dale’s Cone of Experience, which looks at the retention of data from different learning methods, and some accompanying retention data that states that humans retain 10% of what they read and 90% of what they do (Dwyer 2010). However, these values have no basis in studies and upon closer examination are far too exact to be empirical evidence (Dwyer 2010, Deepak Prem, Michael et al. 2014). These papers all agree that the use of Edgar Dale’s Cone of Experience is not accurate and because of this more investigation is needed into how people learn and what methods are the most effective for teaching skills.

Serious games are a form of gamification that can include virtual reality (VR) that are designed to teach skills in an engaging manner (Djaouti, Alvarez et al. 2011). These serious games can range from anything such as a complex computer programs to simple paper-based activities. Serious games are used in a wide variety of industries such as aviation, oil and gas, medicine, automotive, tourism, law enforcement, real estate, education, and entertainment (Akhgar 2019, Davey and Hancock 2019, Maugard 2019, Saunders, Akhgar et al. 2019, Shernoff, Von Schalscha et al. 2020). Many of these industries deal with high-risk events or disasters that can be difficult, dangerous, and expensive to train for. Serious games can help to provide this training at a fraction of the cost and without the risk to participants (Akhgar 2019).

Simulation is an effective educational tool that allows for the representation of real-life scenarios to help learners connect the training with real situations. It has often been shown to be superior to traditional forms of teaching and providing lasting results (McGaghie, Issenberg et al. 2010). Not all learning tasks are better performed with simulation however as some are too simple to require it or require complex interactions with other people that are beyond the abilities of current artificial intelligence technology (Pottle 2019).

Virtual reality training can be useful to create believable environments that may be difficult to reproduce in real-life. Interactive Virtual Training for Teachers, a study by Shernoff et al., used virtual reality to help teachers learn how to deal with disruptive students (Shernoff, Von Schalscha et al. 2020). Several of the participants in this study felt that the characters, sounds and the visuals of the virtual reality classroom felt quite realistic to them and helped to draw them into the scenario and feel involved. This program was also self-sufficient in that users did not require an outside operator or the participation of an instructor as a character to run the simulation (Shernoff, Von Schalscha et al. 2020). This allows users to practice at times that are more convenient to them and avoids the additional costs that comes with the requirement of instructors being present. Having the ability to practice alone can also help users to feel more confident and comfortable as they are not worried about constantly being assessed when training.

There have been several previous studies done in the area of virtual reality training and even specifically medical training. These studies were highly important as they helped to show that there were possible benefits to be gained through the use of virtual reality training as well as work as a guide towards designing the experiment.

Haerling (Haerling 2018) looked at VR training for nurses comparing virtual reality training with traditional mannequin-based training. Their study tested students' knowledge before the training and afterwards as well with several students also participating in a test with an actor at the end. They found similar improvements in skill levels between students who trained with the mannequins and those with VR. However, the virtual training was done at a third of the cost of the physical training (Haerling 2018). This was one of the earlier studies examined for this report and helped to showcase one of the major benefits of virtual training. This reduction in cost has also been shown in other studies comparing virtual reality training and physical training (Larsen, Soerensen et al. 2009, Mills, Dykstra et al. 2020).

Larsen et al. trained surgeons using virtual reality to perform a laparoscopic surgery, the surgeons were spilt into two groups with one training in virtual reality and the other training in traditional methods. After training both groups performed an observed surgery which was marked and timed by an instructor. In this surgery the surgeons who had been trained in virtual reality performed the surgery achieved a higher score and managed to complete the surgery in half the time of the other group on average (Larsen, Soerensen et al. 2009). This faster performance is critical as less time in surgery can reduce the chance for infections as well as significantly lower the cost of the surgery. The training time for the virtual reality group was also slightly lower than their peers. These findings are crucial as they are one of the few studies that show the transference of skills in the virtual world to real life compared to most studies which only test using training exercises.

Similar to the study by Larsen et al., Raque et al. also did a study on virtual reality training for endoscopic surgery comparing virtual reality trained surgeons with bedside trained surgeons. They found an increased cost in the training of the virtual reality group largely due to the expense of the virtual reality devices themselves. Including a cost of $715USD per resident for the virtual reality devices lead to a cost comparison of $1182.79USD for simulated learning and $436.86USD for bedside learning (Raque, Goble et al. 2015). They also discovered no statistically significant difference in the skills or learning speed of the two groups, concluding that in this instance virtual reality training was not preferable due to the higher cost. They also found no reduction in time spent on learning residents by the faculty staff from the use of virtual reality.

Lerner, Mohr, Schild, Goering and Luiz did a project called EPICSAVE (Enhanced Paramedic Vocational Training with Serious Games and Virtual Environments) where they investigated a multi-user virtual reality training program where users responded to an instance of anaphylactic shock in a young girl (Lerner, Mohr et al. 2020). This study focussed on improving users' non-technical skills such as their clinical reasoning and cooperation rather than technical skills of physically applying treatment. They used pre-tests and post-tests to measure users' knowledge gains as well as using an evaluation score called the Training Evaluation Inventory. To gauge their user's engagement in the training they also used a series of questionnaires for users to evaluate the virtual training. Overall, they found that users were strongly engaged with the training however they found only a small increase in post-test score from the users (Lerner, Mohr et al. 2020). Users experience with the training was affected by some hardware limitations from the wired virtual reality headsets used and it was believed that the use of wireless ones would help to alleviate this issue. For the suprascapular nerve block project, a wireless headset was used, and these issues were not encountered which supports their conclusions.

Medical use of virtual reality is not just limited to training, it can also be used to help with patient rehabilitation. This was investigated with stroke patients by Gamito et al. in 2017. They found that virtual reality programs could improve the recovery of stroke patients over a 4-6 week treatment period (Gamito, Oliveira et al. 2017). They also found that virtual reality provided an increased interest in the rehabilitation process by their patients as well as providing easier access through the portability of virtual reality devices. However, it should be noted that their study compared the benefits of virtual reality rehabilitation against a waiting list control group who did not receive any other form of rehabilitation during the study. Because of this it is hard to say how the virtual reality rehabilitation compares to traditional methods.

One of the harder areas to train medical staff in is large scale disaster management, these are low frequency but high casualty events where staff must respond quickly and accurately to treat a large number of patients (Gout, Hart et al. 2020). As these events are low frequency it is difficult for staff to develop and maintain skills through experience and instead this must be done through training. However large-scale events can be very costly to recreate in real-life with numerous actors, props and locations required. The use of virtual environments can help to minimise this cost as shown by Gout et al. in their disaster management training program. They used a third-party platform called Second Life and had initial purchase costs of around $400USD and an ongoing cost of $249 a month as well as time spent building the environment using the programs assets. This allowed them to create several scenarios however including responding to stampedes, bombings, earthquakes, fire, and vehicle crashes, all in a variety of locations. This platform also allowed for large numbers of participants at the same time with them having over 50 users at once. To achieve this in the real-world would come at a far greater cost, especially when considering that the virtual training can be easily repeated as needed.

Disaster management training has come into greater focus due to the global COVID-19 pandemic in recent times. This has highlighted the lack of preparation and skills that medical practitioners have for disaster situations with many responses being slow or prone to errors (Tin, Hertelendy et al. 2021). With the input of new and more advanced virtual reality devices being released development is needed to help improve the training of these skills and prevent repeated mishandling of disasters.

The overall view of virtual reality medical training from the literature reviewed is that it can provide tangible benefits to the development of a user's skills and in a cost-effective manner. However, not all literature agrees with this viewpoint and the benefits can vary significantly depending on the particular skills practiced in virtual reality and the quality of the program. Advancements in virtual reality technology as well as the decreasing price of the devices is also contributing to the interest in virtual reality training, not just in medicine but across industries. However, additional study and proof of tangible benefits is required before virtual reality training can become widespread in the industry.

The medical field has long had issues with training, as mentioned before difficulties can arise with finding suitable participants for students to train on but even more mundane forms of training can be expensive. With staff costs, actors, medical supplies, dummies and other required resources quickly increasing the price (Mills, Dykstra et al. 2020). Several studies in VR have found significant cost savings however through the use of virtual reality simulations (Haerling 2018, Pottle 2019, Mills, Dykstra et al. 2020). Whilst this comes with one-time costs for development of the simulation and the purchase of virtual reality devices this is quickly reduced by large scale use of the training. Other kinds of simulation training are quite common in medicine such as using actors and mannequins or other props. For complex situations however, these can often be quite expensive to set up and run. In some situations it is estimated that virtual reality training can come at one tenth of the cost of training using non-virtual simulations (Pottle 2019).

Usability is an important aspect of any program especially when designed for educational use. This is because the program must be easy and desirable to use by both the students and the instructors, as if either group is disinterested then the program will not be used. Usability was also important when designing the survey questions as these questions will provide feedback and guidance for the future goals of the project. To accomplish this the System Usability Scale or SUS was used which has had considerable use and testing in the usability area (Brooke 1996, Bangor, Kortum et al. 2008). The SUS allows the calculation of a score that gives an overview of the usability of an entire system and a copy of the post training survey which utilises this has been included in the Appendix A.

Whilst this project is low budget and on a smaller scale the goal is still to create accurate results for the usability of VR in training. To ensure that this was achieved a study by Nielsen, a leading expert in usability, was examined as well as follow up work which discusses the ability of small study groups to provide extensive usability reviews (Nielsen and Landauer 1993, Nielsen 2000, Nielsen 2012). These studies will help to legitimise the results created from the small sample of users.

The SUS is a robust system and is able to get accurate results with only small sample sizes, Tullis and Stetson compared several questionaries and found that using the SUS questionnaire with small sample sizes will still usually get a similar result as would be found when using larger sample sizes (Tullis and Stetson 2004). They found that the SUS was able to do this with greater accuracy and less participants than the other surveys examined even with its very simple and quick use of only 10 questions.

Bangor, Kortum and Miller evaluated the SUS to discover how reliable it was after widespread usage of the questionnaire. As part of this they calculated Cronbach's alpha for the SUS and found it to be equal to 0.91 (Bangor, Kortum et al. 2008). As a value of 0.7 or higher is considered to be acceptable, however values above 0.9 whilst still showing reliable data show that there may be too much similarity between questions and it is possible to shorten the test questions (Tavakol and Dennick 2011). This is possibly the case with the SUS as a study by Lewis and Sauro found that they achieved similar SUS scores when leaving out a question from the SUS and only using nine values (Lewis and Sauro 2017). This was the same regardless of which question was left out providing the opportunity to remove a question that does not fit the particular study. Such the one asking if users they agree they would use the system frequently when the system in question is not designed to be used frequently. For this report however the entire set of questions for the SUS were used as there was no need to remove any questions and the considerable literature backing up the standard SUS was determined to justify the normal use.

METHODOLOGY

There were two main stages in completing this project, first the software development stage where the virtual reality program itself was designed and created. Secondly, there was the experimental analysis stage, where users were able to experience and evaluate the program.

Development Process

To test the effectiveness of virtual reality in the teaching and training process of the suprascapular nerve block procedure, a virtual reality training program had to be made. This was designed, prototyped, and developed as part of this project.

The first stage of creating the program was a planning and design process. This involved determining what procedure would be performed in the program and how it would be structured. To decide upon a procedure that would be both beneficial to the medical industry as well as practical to be created in the timeframe of this project, Professor Michael Shanahan was contacted. Professor Shanahan is a Professor of Musculoskeletal Rheumatology Medicine from the College of Medicine and Public Health at Flinders University. He is a respected professional in the medical industry and has been involved in the publication of many research articles throughout his career. In his current position he is involved in the training of rheumatology registrars at Flinders Medical Centre. Due to his connections to both the medical field and the educational sector he was able to assist with ideas and inside knowledge of the desired requirements for a virtual reality medical training program. Through email communication and face to face meetings he was able to help guide the complex medical representation in the virtual reality program and ensure that the proper techniques were used.

The development of the program was done through Unity. Unity is a cross-platform game engine that has been used for many different projects worldwide. It was chosen for this project for several reasons, firstly it was the game engine that the researcher had the most familiarity with, therefore accelerating development time. It also allows for quick and easy testing on the virtual reality device and a free version is available for use for student projects. Unity also has an extensive asset store which was used to acquire some assets for the program, this helped reduce development time as detailed 3D modelling was beyond the skill set of the developer.

The virtual reality device that the program was deployed to and tested on was the Oculus Quest 2. This is a standalone headset that was released in late 2020 and as such is one of the latest virtual reality devices available. This headset was used for two main reasons, it is a standalone headset, and it was the equipment that was available through the university. As a standalone headset it does not require a connection to an external computer to run the virtual reality. This means it is not as powerful as some other devices, however the added portability and lack of reliance on a powerful computer to run the development meant that this was key for the success of a final commercial deployment of a functioning training application. If the tools required to interact with this experience were all contained within the device and did not require hardware connections, sensor setup and a powerful computer, the training program could be utilised anywhere by the target audience and not in specialised facilities. Also, this device was available for use through the university which enabled easy and consistent access for the research team.

To help structure the development and the overall project a Gannt chart was used to set milestones and track progress throughout the project, this Gannt chart has been included in Appendix C. A plan was also sketched out to determine what features would be in the virtual reality program as well as detailing some possible extensions that could be added depending on the time taken for development.

The first step after acquiring the Oculus Quest was to test the deployment method for running Unity projects on the virtual reality headset. To evaluate this process a simple sample project was used and then an executable file (APK) was built and deployed to the headset. This process was slow and not practical for use in the iterative development of the program. Unity has a feature that allows for simple testing of a program through the game editor, this has some issues when developing for virtual reality. This is because Unity is run on the computer and the testing process uses the standard computer controllers such as keyboard and mouse which do not handle virtual reality well. To overcome this issue an experimental feature of the Oculus Quest 2 which allows for a wireless link to the computer to use the Oculus headset as an accessory of the computer was used. This allowed for quick and simple testing of the training program. Having quick testing is highly important for virtual reality programs as the image displayed on a computer screen is significantly different to how that image will be presented in virtual reality. This is due to the difference in the field of view, as well as the zoom and positioning of the camera, compared to how it appears in the editor.

This program was required to be used by users who may not have any experience with virtual reality, therefore it was important that design consideration was applied to making the application accessible and intuitive. This meant that the number of controls that they had to learn had to be minimised, thereby preventing confusion, and reducing the chance of errors. The size of the level, or world, that users were able to navigate was also minimised to allow for real world movement around the playing area rather than through the use of hand-held controls.

There are several methods of moving around the virtual world in virtual reality, users can walk around in real life, use gaze controls, use additional tracking devices, or use controller-based movement. To move by walking users simply walk around the real-world area set aside for the virtual reality and this movement is tracked and followed by their character in the virtual world. Gaze controls allow for users to look in a particular direction and then they will move in that direction in the virtual world. Additional tracking devices such as smart phones or specially designed hardware can be attached to a user's legs and allow for movement to occur when they walk or run on the spot. Controller based movement is usually either linear movement, where they will move in a direction consistently through the use of the controls, usually the thumb sticks on the controllers, or teleportation. Teleportation will allow users to select an area they wish to move to and then instantly move them to that location, usually with a quick fade to black of the screen to help them adjust to the sudden movement.

The main problem with all types of movement other than real-life tracking is that they can cause motion sickness in users as the brain receives mixed messages as it can see the movement but your body is actually staying still. Teleportation or additional tracking devices can help to reduce this however there is still some possibility of it occurring especially with novice users of virtual reality such as a majority of the participants in this study. These two methods can be hard for users to learn as well and using additional tracking devices would increase the complication of the development significantly as well as require the use of additional devices. As this program only required a smaller area it was determined that ensuring users could simply walk normally around the virtual world would provide the greatest benefit and help to reduce the chance of motion sickness.

This helps to reduce confusion for users as well as reducing the risk of motion sickness that is associated with movement in the virtual world. To prevent accidental movement by the users touching the thumb-sticks, the default controls were removed to only allow movement through tracking their real-life movements.

As there are several different types of virtual reality devices available which often operate on different systems, Unity does not natively interact with each type of device and instead requires certain plugins to correctly recognise and communicate with the devices. For the Oculus Quest 2, a plugin was used called Oculus Integration which is created by Oculus for developers to connect their designs with Oculus devices. This plugin allows for tracking of the users' movements to be displayed in the program as well as allowing for them to interact with objects using the controllers.

While the idea behind the training program is to stick to the real-world aspects of the actual procedure, some concessions were made to make it easier for the users to interact with the virtual world and reduce the complexity of their experience. This is most obviously shown through the lack of gravity with the various tools used in the training program. When a user lets go of a pen, needle, or other tool in the training program it will simply stay in the position they left it. This allows for users to easily pick objects up again if needed without having to worry about if it fell to the floor and rolled away. As some users may be new to virtual reality, and possibly gaming in general, they may also struggle more with the controllers which could cause them to accidently let go of objects while using them. If gravity was enabled, they could spend a considerable amount of time trying to pick objects back up and chasing after them, which can cause issues due to the limited real-world space around the user.

As is common with development, several issues were encountered during the project. These issues related to the code, specifically the scripts that control many of the interactions present in the program, as well as in the Unity game engine itself.

One unusual issue encountered was due to the difference in height between one user and the developer. This caused the user's point of view, who was slightly taller than the developer, to be pushed through the roof of the medical office when starting the program. However, this would only occur when that specific user used the application, which caused some initial confusion as to the cause. This was fixed by scaling down the size of all users so that they would not experience this bug.

Unity is a frequently updated piece of software and when developing this project several other plugins and assets were used that each have their own update schedule. This caused problems with the program and introduced errors where some parts of the program were running on a different version to other sections and became incompatible. One significant issue that was encountered due to this was a rendering issue with the model used for the patient. This error caused the patient to not render, meaning that when loading the program, the patient could not be seen at all, which meant the program was essentially unplayable. As this model was not created by the developer, updating the code for the model was not a practical solution. The code causing the error was quite complicated and interacted with several other different scripts. Whilst efforts were made to fix this issue with current versions, the only solution was to utilise the version management system and roll back to a previous version of the project to ensure the different sections were able to work together properly.

However, in the final version of the application, this model of the patient was not used due to feedback that the spine of the scapula, which is needed for the user to identify the entry point for injection, was not prominent enough to help guide the users. While users would normally be able to also rely on touch in a real-life procedure, in virtual reality they are reliant on what they can see to guide them to the correct locations. This problem was more difficult to fix than originally assumed, as most models do not show this part of the human anatomy clearly, as it is not required for normal usage and would not be missed by a majority of users. The new model with better representation of the spine of the suprascapular is shown below in figure 1.

Figure 1 New patient model with greater definition of suprascapular bone

The guidance of Professor Shanahan was important to ensure that the virtual reality program was as accurate as possible to the real-life procedure. As the developer had no medical background, Professor Shanahan was consulted to ensure that the training program would not be misleading to users or cause frustration through poor wording or requirements. It was also important to find the required accuracy for the procedure, as it would be impossible for all users to always mark the exact same spot for entry, both in virtual reality and the real world, some leeway was needed. However, if too much leeway was granted this would allow for potentially dangerous injection points to be counted as correct.

Experimental analysis

The most important section of the project was testing the effectiveness of the virtual reality training program and examining the results gained from this. This testing process was performed with the assistance of Professor Shanahan who helped provide access to current registrars in the rheumatology field. These registrars were invited to participate by using the virtual reality training program and answering questions to detail their opinions on the program. These questions included some general demographic questions as well as specific ones related to their use and familiarity with virtual reality devices. It also utilised the System Usability Scale (SUS) a series of 10 questions on a Likert scale that can be used to compare the usability of different systems and software. The results and analysis of the SUS are supported by extensive research and is used as an industry standard.

To allow for the participation of people in this experiment an ethical application was required by Flinders University. The ethics application was completed and approved by the Human Research Ethics Committee of Flinders University (Project ID 4464), see Appendix B for the approval letter. Medical participants were recruited through email communication facilitated by Professor Shanahan with potential applications forwarded an introductory letter and contact details for the researcher. Additional non-medical participants were recruited from associates of the researcher. All participants were informed of the purpose of the study and consented to the use of their non-identifiable data to be used for the paper.

Professor Shanahan also completed the training program and provided his answers to the questions where appropriate. As his medical experience was considerably higher than that of the registrars his results and answers were kept separate, however the comparison was considered useful for the final results. This expert evaluation was also critical in understanding the educational value of the simulation.

To set up the experiment registrars were recruited through email and invited to email the researcher if they were interested. As there are only three Rheumatology registrars at Flinders Medical Centre at any one time the sample size was quite limited. To further bolster this small number of registrars, other medical personnel who worked in the same area as the registrars were also invited to participate. This included two residents and one medical student, two other doctors in different specialties were also invited to participate. Unfortunately, two of the Flinders Medical Centre registrars were unable to participate in the end as one was away at the time of the evaluation and another one was busy with patients and was unable to spare the time. Nevertheless with the last registrar's participation as well as that of five other doctors and a medical student, this can still provide a suitable analysis of the virtual reality program, especially when the results from the medical expert are considered as well.

For the experiment itself the doctors were met at Flinders Medical Centre at Bedford Park. Once they arrived the researcher explained how the virtual reality program would be used as well as detailing what controls the participant would need to operate it. They were also assigned a unique ID which would be used to link all the data gathered from their participation and remove any identifiable data.

The participants then answered some pre-training demographic questions. Once these questions were answered they were able to begin using the virtual reality headset. Screen recordings of their usage were taken to help further examine any difficulties they may have had with the training program. Some details from their attempts were also recorded such as the number of errors made, the time taken, and the recording of the location of the entry point that they used. The results achieved by the registrars in this data were likely to be poorer than could be expected due to their unfamiliarity with virtual reality and the program itself. It is expected that with continued use and practice they would be able to achieve far better scores. A participant can be seen below performing the nerve block injection in figure 2.

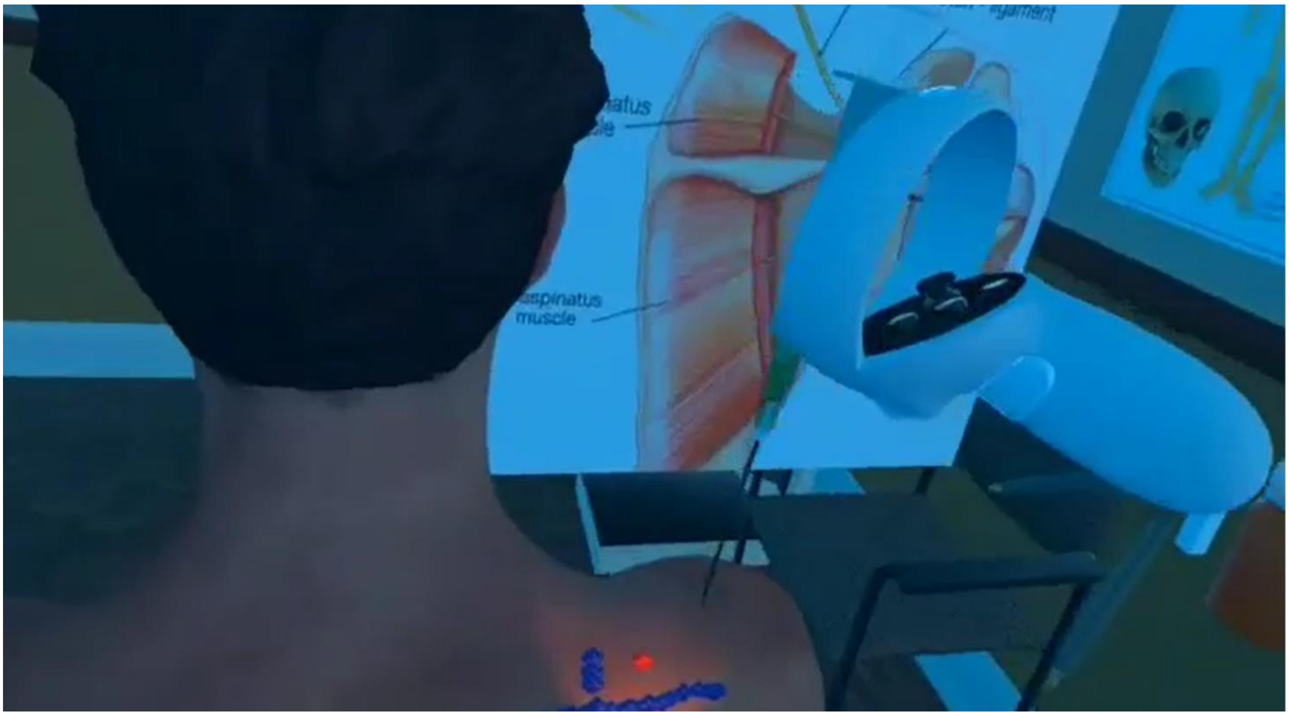

Figure 2 Participant performing nerve block

Once the participants had completed the training program, they were asked to complete the post virtual reality survey which included the SUS questions as well as some general feedback on their experience using the virtual reality program.

These results were then collated and analysed, and the two surveys and virtual reality program results were linked to examine any connections between them.

To generate additional data on the usability of the virtual reality program some non-medical participants were also recruited. These participants went through the process slightly differently as they did not possess the medical knowledge to understand some of the instructions and terminology in the program. To overcome this, they were given an explanation of the procedure and any medical terminology used within the program to help them understand the tasks they had to accomplish. As these participants were not the target audience of the virtual reality training the data gathered from them is not as useful as that from the doctors. They were, however, able to provide valuable information on the use of the controls and issues with the layout and methods in which the instructions were given.

RESULTS

The original intent of this project was to evaluate the virtual reality training just with rheumatological registrars who would be familiar with the procedure and have performed it before but not frequently. This would ensure that they were able to draw similarities between the virtual reality representation and the real-life procedure and determine if it was a fitting substitute or if it was missing any required parts.

However due to limited numbers of registrars and the difficulty in finding an appropriate time to test it with them several other participants were also invited to be part of the training process. This included nonrheumatological doctors and a medical student as well as some participants who were not medically trained at all. The non-medically trained participants were unable to comment on the accuracy of the virtual reality training to the procedure however they were still able to judge the usability of the training program and its controls.

The results were gathered from two main sources, the answers that participants gave in the surveys as well as some basic in-built evaluation of their performance through the program. This evaluation consisted of recording the co-ordinates of where they placed the entry point, the time they took to complete the program and the number of errors that they made. The error detection was quite basic and not intended to be a final form of evaluation but was included as an example of possible ways to represent this.

The primary source of evaluation for the training program was the System Usability Scale, the ten questions for this in the second survey were used to calculate a score for the group as well as spilt amongst different demographics to identify trends. The different groups used to split the results were doctors against non-medical participants, gamers against non-gamers, male against female and those over the age of 35 against those under. For the purpose of this study gamers were determined as those who spend more than an hour gaming each week. Table 1 below shows the average scores for each question as well as the average SUS score for each group. The scores for each question are added up in a specific way to calculate the final value as determined by the usage of the SUS. All odd questions area added together and then five is subtracted from the sum to give a score between zero and four for each question. Then odd questions are summed and subtracted from twenty-five, the two values are then added together and multiplied by two and a half to generate a score out of one hundred. This calculation gives each question a weighting of ten and ensures that the odd questions which are positive about the software add to the score with high values and the even questions which are negative detract from the score.

Table 1 SUS scores split by demographic groupings

	Everyone	**Doctors**	**Non-Medical**	**Gamers**	**Non-Gamers**	**Male**	**Female**	**Above 35**	**Under 35**
Number in Group	12	5	6	4	7	6	5	5	6
Question 1	4.27	4.00	4.50	4.50	4.14	4.00	4.60	4.20	4.33
Question 2	1.73	2.20	1.33	1.75	1.71	1.83	1.60	1.40	2.00
Question 3	4.36	4.00	4.67	4.00	4.57	4.17	4.60	4.40	4.33
Question 4	2.64	3.20	2.17	3.00	2.43	2.67	2.60	2.60	2.67
Question 5	4.18	3.60	4.67	4.50	4.00	3.83	4.60	4.00	4.33
Question 6	1.45	1.60	1.33	1.75	1.29	1.67	1.20	1.40	1.50
Question 7	4.27	3.80	4.67	4.00	4.43	4.17	4.40	4.40	4.17
Question 8	1.42	2.00	1.00	1.75	1.29	1.50	1.40	1.60	1.33
Question 9	3.82	3.40	4.17	3.25	4.14	3.33	4.40	4.00	3.67
Question 10	3.00	3.00	3.00	2.75	3.14	3.33	2.60	2.60	3.33
Total SUS Score	76.65	67.00	84.58	73.13	78.57	71.25	83.00	78.50	75.00

General feedback was sought from the participants to identify any issues that were not covered by the survey questions. Two particular pieces of feedback appeared several times as well as in comments made by participants while they were using the program. Firstly, that the image that helped to track the movement of the injecting needle through the patient's body was not well announced, and that they struggled with understanding some of the instructions.

When users were performing the nerve block itself an image of the anatomy of the area was shown with the major bone structure as well as muscles and the suprascapular nerve itself displayed on the image. When users started to insert the needle into the patient a copy of the needle they were holding was shown on this image and followed their movements. However, several users didn't notice this at the beginning and missed out on being able to use this to help guide them as it was not announced in the instructions.

The two main issues with the instructions that users had were related to when they mark the patient's body. The first time they mark the body with a blue pen to locate the point of injection and then they mark the injection point with a red pen. In the instructions in the program this is broken up into two sections due to the length of the instructions, the part telling them to use the blue pen in only on the first page and the detailed instructions for how to mark the patient with the blue pen is on the second page. The second page also mentions marking the injection point with the red pen. This led to some confusion where users were unsure if they had to mark the patient completely with the red pen. For future iterations of this program these instructions would be re-worded to remove this confusion and more clearly detail what is expected of users.

Users also had difficulty in locating the entry point as whilst the program would inform them if they were in the wrong position, it did not tell them how far away they were or in which direction they needed to move it. This caused frustration for some users as they were unsure where they had gone wrong and started simply guessing possible locations until they got it right. One positive side effect of this was that some users instead went back to their original markings with the blue pen and redid them. When redoing these lines and taking greater care they were able to create a more accurate marking of the patient's body which helped them to find the entry point when they tried again. Nonetheless there still needed to be some guidance given to the users to prevent the frustration as well as to teach them the proper location.

ANALYSIS

Table 2 SUS gradings (Lewis 2018)

SUS Score range	Grade	Percentile range	Adjective	Acceptable	Net Promotor Score
84.1-100	A+	96-100	Best Imaginable	Acceptable	Promotor
80.8-84.0	A	90-95	Excellent	Acceptable	Promotor
78.9-80.7	A-	85-89		Acceptable	Promotor
77.2-78.8	B+	80-84		Acceptable	Passive
74.1-77.1	B	70-79		Acceptable	Passive
72.6-74.0	B-	65-69		Acceptable	Passive
71.1-72.5	C+	60-64	Good	Acceptable	Passive
65.0-71.0	C	41-59		Marginal	Passive
62.7-64.9	C-	35-40		Marginal	Passive
51.7-62.6	D	15-34	Ok	Marginal	Detractor
0.0-51.6	F	0-14	Poor	Not Acceptable	Detractor

The SUS values from table 1 show an overall score of 76.65 from the participants with a standard deviation of 15.16, this is above the industry average of 68. Table 2 shows how the different SUS scores correlate to a marking grade. 76.65 puts the training program in at the high end of a flat B grade, however there are some factors to take into account with this score. Firstly, this score is based on all the participants in the study and the scores between the doctors and non-medical participants varies greatly with the doctors giving a score of 67 to the non-medical score of 84.58. A significant difference of 17.58, as the doctors are closer to the intended audience their score is more valuable for the study. Part of the reason for the non-medical score being so much higher is likely due to the increased amount of explanation and guidance that they received for the training program to help them deal with their lack of medical knowledge and understanding of the procedure. As this was specific to the training module this would have helped users to use the module with greater ease and thereby reduced any frustration they may have felt from their difficulties. Another possibility for the difference in scores is that one of the doctors SUS score was considerably lower than the other participants. This participant answered the first eight questions all in the middle of the scale, which while possible is unusual. It is possible that the participant did not complete the survey properly and this could have skewed their results. Removing that doctors score from the doctor's average provides a score of 75.63 which is still below the non-medical score but also significantly above the overall doctor's score. Another interesting factor is that Professor Shanahan also filled out a survey to find his SUS score and had a value of 80. This was well above the overall doctor's average and in fact above the overall average. Professor Shanahan did however have some familiarity with the program through his use of it throughout development and many of the changes made were in response to his feedback. As such it is expected that he would have less issues with the program as it had been designed with his method of use in mind. It is also possible that this difference is due to his experience with the procedure itself especially as the only other participant who had completed a nerve block before also found the virtual training easier than other users. Whilst users who had completed the procedure before would be expected to perform better it is also possible that the difficulties experienced by the others may be due to the instructions they were given during the virtual training in the program itself. As while the instructions may have been enough with those familiar with the procedure the assumptions made of users could have been too great for those who had not completed a nerve block before.

From examination of the individual responses and scores of users it is possible that some users SUS scores were artificially inflated due to the novel factor of virtual reality for them and their interest in the use of the software. This is hard to determine for sure however as only two participants felt confident using a virtual reality device out of the total twelve and neither of them were frequent users. Virtual reality programs were still fairly novel to all participants therefore and comparisons could not be made to users who had extensive experience. This issue could potentially have been alleviated with either several stages of usability testing with the same cohort or a larger sample size which may have included more participants with virtual reality experience.

One thing to consider when looking at the SUS scores from this study is that this is the first usability test conducted with participants other than Professor Shanahan. Most software will go through several stages of usability testing before release as early tests are likely to find several problems. This was also affected by some of the limitations placed on the development which meant some features were not in a final state.

Lerner, Mohr, Schild, Goering and Luiz when doing their study on virtual reality training also calculated a SUS score for their participants and had a score of 65.56 (Lerner, Mohr et al. 2020). This is slightly lower than the score given by the doctors in this study. Lerner, Mohr, Schild, Goering and Luiz however, used wired headsets for their study which resulted in some difficulties for their user's movement during the training which was believed to have negatively impacted their scores.

For this study a large portion of the participants had not used virtual reality much, if at all, beforehand, and with the current high costs of devices for private consumers this is unlikely to change in the near future. This means users are not used to the controls and can quickly become confused if the training program is complicated and, this makes it harder for them to use which can lead to frustration in users and lower usability scores.

The participants at Flinders Medical Centre were also in the room where the program was tested when earlier users were testing it as the area available was a shared office space for them. This meant that the later users may have had some unfair advantage when participating in the virtual reality program. Meaning they may have had less issues with the controls or use of the program and therefore looked upon it more favourably. To maintain an even assessment from all users they should have been kept separate from the testing area until they were ready to participate. This was not possible however as the testing area was a work area for several of the participants and they could not therefore be kept away from it for the study.

The overall SUS score is likely to be at least close to a true value for this stage of development as according to Tullis and Stetson's work on evaluating the SUS and other questionaries, with 11 participants the score generated by the SUS should approximate a score with a higher sample size (Tullis and Stetson 2004). This means that it can be assumed that most users would be positive about using this form of virtual reality training.

DISCUSSION

Review of Methodology

Some issues with the methodology will limit the knowledge gained from this study. This is mostly due to the short time frame in which testing was completed which caused a reduced number of registrars to be able to complete the program and surveys. Whilst this was offset through the addition of other medical professionals and non-medical participants, as they were not the targeted audience it was not ideal.

Part of the original planning stage was devoted to structuring a Gannt chart to help ensure that certain milestones were met in time and the project did not have issues with testing times for participants. This timeline however was optimistic with the time spent on initial research and the development of the program and did not allow extra time for the difficulties faced during this development stage. Due to this the project fell behind on the timeline and was never able to fully catch back up causing the testing stage to be limited and rushed.

One method of reducing this issue would have been to limit the features available in the training program, however this may have caused it to be an unsatisfactory tool and reduced the interest of the users. It is possible that combining the research, development and testing of the training may have been too extensive a project for the time frame available.

Other than the delays in the development of the program however the development stage worked quite smoothly. With multiple meetings with Professor Shanahan throughout the development the researcher was able to make changes throughout the development to ensure that it matched the procedure as accurately as possible. This also allowed Professor Shanahan to evaluate multiple iterations of the program and provide feedback to the researcher.

Limitations

This project was limited in scope due to the fact that the virtual reality program had to be developed by the researcher throughout the project. This development was a lengthy process and whilst this enabled the creation of the program to match the goals of the project rather than trying to adjust a pre-existing program it did take away from time that could otherwise have been spent on a wider investigation of existing research and limited the time available for usability tests with the targeted medical professionals. As the researcher was developing the program by themselves this also meant the program was limited by the time and skills that they possessed. As the researcher was not as skilled in 3D modelling this meant that models needed to be found and purchased for use in the program which did mean they could not always match the desired look. The limitations in design were mostly overcome through the use of these third-party models however and some minor alterations performed by the researcher. But the time taken to fix these issues did reduce the time that could be spent improving the program and the addition of additional features or the improvement of existing ones.

The time limitation greatly affected the testing of the training program as it meant that several of the desired participants were unable to test the program. As discussed, earlier testing with a larger cohort of the targeted audience would have been beneficial in creating a more accurate evaluation of the program.

Larger sample sizes could also open up the possibility of splitting the participants with some being involved in the virtual training and some not. This would enable a greater comparison to show if virtual reality can provide an increase in the effectiveness of training the suprascapular nerve block procedure.

Comparisons against other medical virtual reality studies is quite difficult due to the difference in methods, devices, procedures, and programming in each study. These factors can all make considerable differences in evaluations of the programs, the use of subjective evaluation as opposed to an objective result causes additional problems especially in studies such as this with small sample sizes. As virtual reality is still a new experience for many participants, comparing virtual reality with traditional methods is difficult as it is often affected by novelty factors which can arbitrarily inflate subjective scores.

CONCLUSIONS

Ultimately this study found a high usability in virtual reality training for the suprascapular nerve block procedure. It did discover significant interest from medical professionals in the use of virtual reality training as well as their beliefs in the potential for programs such as this to help overcome some of the obstacles they face in training. The core question of usability is an ongoing one and will always be dependant on the particulars of the program that has been developed. However, some key points identified in this study from the issues faced are the need for simple and easy to use controls and clear instructions throughout the training program. To cater for new virtual reality users the learning process must be kept simple, and programs should not rely on users having experience and understanding of tools. Instructions must also be clear as if users are not very familiar with the concepts covered in the training, they can struggle to complete the tasks. Clear, helpful feedback should also be provided to users, and this should be built into the program. This is less of an issue if they have an instructor with them to help guide them but to promote individual training instructions should be clear and easy to understand.

Future work

The work achieved in this project was quite limited due to constraints on time and resources available however it does set up a foundation for future exploration into the area of medical virtual reality training.

To fully realise the programs potential some upgrades could be made to the virtual reality program itself, such as adding additional patient models to allow users the ability to practice with different body shapes. This is closer to the reality that doctors would experience as all bodies differ in some way.

Another upgrade could be allowing users to make mistakes when performing the procedure and then creating the complications that would arise from those mistakes. This would be particularly useful in showing how the incorrect entry point can reduce the effectiveness of the procedure and potentially cause harm to the patient.

Improving the needle tracking to allow for a 3D view of the patient's anatomy would help to greater visualise the placement of the needle. Additionally allowing the users to inject the solution and see it disperse in the display image would also help them to see how the solution covers the nerve and provides the pain relief.

Inbuilt scoring of a user's attempts would be beneficial for instructors as it would make their job easier when comparing multiple attempts. This can be used to compare users or see how a user has progressed. Whilst some basic scoring functionality was used in the program, in future work this would be in greater detail and be accessible through the program to allow instructors a visual of errors made by the users.

In regards to experimental analysis, several extra steps could be taken to improve the quality of the results generated from this study. This includes doing further usability studies after changes are made to accommodate the shortcomings found in the first studies. Performing several series of studies will help to find most usability issues as well as any created through other changes. This will provide a more accurate SUS score for the virtual reality training and prevent any reductions that may occur due to bugs or issues that may be missed by the developer.

Evaluating a user on performing a real-life procedure after receiving virtual reality training would help show if virtual reality training is comparable to current training methods. Also examining the long-term retention of skills learnt in virtual reality would be beneficial when examining the effectiveness of virtual reality training.

Improved haptic feedback would help users to better understand the procedure and relate the virtual training with real-life. This could be achieved through the use of physical models that allow users to feel the resistance they would experience when injecting a patient, additionally the use of needles and the other tools used instead of controllers would also help increase the immersion of users. However, this may become too complicated due to the numerous tools used and take away from the ease of which this training can currently be transported and performed.

APPENDICES

Appendix A – Survey Questions

Usability of Virtual Reality for Suprascapular Nerve Block Procedure Training Before Questionnaire

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Start of Block: Pre VR Module Survey Questions

Q1 Research Identification Number

____

Q2 Age Range

- ◯ 18 - 25 (1)
- ◯ 26 -35 (2)
- ◯ 36 - 45 (3)
- ◯ 46 - 55 (4)
- ◯ 55 and over (5)
- ◯ Prefer not to answer (6)

Q3 Gender

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary / Other (3)
- ○ Prefer not to say (4)

Q4 Time spent as a Registrar?

- ○ 0 - 2 years (1)
- ○ 2 - 4 years (2)
- ○ 4 plus years (3)
- ○ Finished Registrar training (7)
- ○ Prefer not to answer (5)
- ○ None (6)

Q5 Which of These Devices do you own or feel confident using?

- ☐ Desktop Computer (1)
- ☐ Laptop (2)
- ☐ Smartphone (3)
- ☐ Console (4)
- ☐ Virtual Reality Headset (Standalone or otherwise) (5)
- ☐ Handheld Device such as Gameboy/ Nintendo Switch (6)
- ☐ Other (Please State) (7) ____
- ☐ None (8)

Q6 Which of the following devices have you used before for gaming purposes?

- ☐ Desktop Computer (1)
- ☐ Laptop (2)
- ☐ Smartphone (3)
- ☐ Console (4)
- ☐ Virtual Reality Headset (Standalone or otherwise) (5)
- ☐ Handheld Device such as Gameboy/ Nintendo Switch (6)
- ☐ Other (Please State) (7) ____
- ☐ None (8)

Q7 If you game, how much time do you spend on it weekly?

- ◯ None (1)
- ◯ 0 - 1 hour (2)
- ◯ 1 - 3 hours (3)
- ◯ 3 - 5 hours (4)
- ◯ 5 - 7 hours (5)
- ◯ More than 7 hours (6)

Q13 Have you used a virtual reality device before?

- ◯ Yes (1)
- ◯ No (2)

Q14 If you have used a virtual reality device before which ones have you used?

- ☐ Smartphone Based (Such as Google Cardboard) (1)
- ☐ Oculus Go (2)
- ☐ Oculus Quest (1 or 2) (3)
- ☐ Oculus Rift (and Rift S) (4)
- ☐ HTC Vive (Including Vive Pro) (5)
- ☐ HTC Vive Cosmos (6)
- ☐ Vive Focus (7)
- ☐ PlayStation VR (8)
- ☐ Valve Index (9)
- ☐ Other (Please State (10) ____
- ☐ Not Applicable (11)

Q15 If you have a VR device how much time do you spend on it weekly?

- ○ None (1)
- ○ 0 - 1 hour (2)
- ○ 1 - 3 hours (3)
- ○ 3 - 5 hours (4)
- ○ 5 - 10 hours (5)
- ○ More than 10 hours (6)

Q8 If known, what learning style are you? (If multiple please select the one you most identify as)

- ◯ Visual (Prefer to learn by watching) (1)
- ◯ Auditory (Prefer to learn by hearing someone explaining) (2)
- ◯ Reading/Writing (Prefer to learn by reading or writing about the subject) (3)
- ◯ Kinesthetic (Prefer to learn by doing the task) (4)
- ◯ Unknown (5)

Q9 Do you suffer from motion sickness?

- ◯ No (1)
- ◯ Rarely (2)
- ◯ Sometimes (3)
- ◯ Frequently (4)
- ◯ Prefer not to answer (5)

Q10 Have you completed a Suprascapular Nerve Block before?

- ◯ Yes (1)
- ◯ Completed with assistance (2)
- ◯ Watched but not done it yourself (3)
- ◯ No (4)

Post VR Training Survey

Start of Block: Post VR Training Survey Questions

Q1 How did you find the VR module

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
	1	2	3	4	5
I found it realistic. ()					
I suffered from motion sickness. ()					
I found the image quality high. ()					
I found the headset to be comfortable to wear. ()					
I enjoyed the exercise. ()					
VR modules like this would encourage me to do additional practice. ()					

Q3 How does the VR version compare to the real life procedure?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	Not Applicable
	1	2	3	4	5	
I found the VR version similar to the real life procedure. ()						

Q2 How did you find the usability of the device?

	Strongly agree 1	Somewhat agree 2	Neither agree nor disagree 3	Somewhat disagree 4	Strongly disagree 5
I think that I would like to use this system frequently. ()					
I found the system unnecessarily complex. ()					
I thought the system was easy to use. ()					
I think that I would need the support of a technical person to be able to use this system. ()					
I found the various functions in this system were well integrated. ()					
I thought there was too much inconsistency in this system. ()					
I would imagine that most people would learn to use this system very quickly. ()					
I found the system very cumbersome to use. ()					
I felt very confident using the system. ()					
I needed to learn a lot of things before I could get going with this system. ()					

Q4 Do you have any additional comments/feedback you would like to add?

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End of Block: Post VR Training Survey Questions

Appendix B – Ethics Approval

8 July 2021

HUMAN ETHICS LOW RISK PANEL

APPROVAL NOTICE

Dear Dr Brett Wilkinson,

The below proposed project has been **approved** on the basis of the information contained in the application and its attachments.

Project No:	4464
Project Title:	Usability of Virtual Reality for Suprascapular Nerve Block Procedure Training
Primary Researcher:	Dr Brett Wilkinson
Approval Date:	08/07/2021
Expiry Date:	20/10/2021

***Please note:** Due to the current COVID-19 situation, researchers are strongly advised to develop a research design that aligns with the University's COVID-19 research protocol involving human studies. Where possible, avoid face-to-face testing and consider rescheduling face-to-face testing or undertaking alternative distance/online data or interview collection means. For further information, please go to https://staff.flinders.edu.au/coronavirus-information/research-updates.*

RESPONSIBILITIES OF RESEARCHERS AND SUPERVISORS

1. Participant Documentation

Please note that it is the responsibility of researchers and supervisors, in the case of student projects, to ensure that:

- all participant documents are checked for spelling, grammatical, numbering and formatting errors. The Committee does not accept any responsibility for the above mentioned errors.
- the Flinders University logo is included on all participant documentation (e.g., letters of Introduction, information Sheets, consent forms, debriefing information and questionnaires – with the exception of purchased research tools) and the current Flinders University letterhead is included in the header of all letters of introduction. The Flinders University international logo/letterhead should be used and documentation should contain international dialing codes for all telephone and fax numbers listed for all research to be conducted overseas.

2. Annual Progress / Final Reports

In order to comply with the monitoring requirements of the *National Statement on Ethical Conduct in Human Research 2007 (updated 2018)* an annual progress report must be submitted each year on the approval anniversary date for the duration of the ethics approval using the HREC Annual/Final Report Form available online via the ResearchNow Ethics & Biosafety system.

Please note that no data collection can be undertaken after the ethics approval expiry date listed at the top of this notice. If data is collected after expiry, it will not be covered in terms of ethics. It is the responsibility of the researcher to ensure that annual progress reports are submitted on time; and that no data is collected after ethics has expired.

If the project is completed *before* ethics approval has expired please ensure a final report is submitted immediately. If ethics approval for your project expires please either submit (1) a final report; or (2) an extension of time request (using the HREC Modification Form).

For student projects, the Low Risk Panel recommends that current ethics approval is maintained until a student's thesis has been submitted, assessed and finalised. This is to protect the student in the event that reviewers recommend that additional data be collected from participants.

3. Modifications to Project

Modifications to the project must not proceed until approval has been obtained from the Ethics Committee. Such proposed changes / modifications include:

- change of project title;
- change to research team (e.g., additions, removals, researchers and supervisors)
- changes to research objectives;
- changes to research protocol;
- changes to participant recruitment methods;
- changes / additions to source(s) of participants;
- changes of procedures used to seek informed consent;
- changes to reimbursements provided to participants;
- changes to information / documents to be given to potential participants;
- changes to research tools (e.g., survey, interview questions, focus group questions etc);
- extensions of time (i.e. to extend the period of ethics approval past current expiry date).

To notify the Committee of any proposed modifications to the project please submit a Modification Request Form available online via the ResearchNow Ethics & Biosafety system. Please note that extension of time requests should be submitted prior to the Ethics Approval Expiry Date listed on this notice.

4. Adverse Events and/or Complaints

Researchers should advise the Executive Officer of the Human Research Ethics Committee on at human.researchethics@flinders.edu.au immediately if:

- any complaints regarding the research are received;
- a serious or unexpected adverse event occurs that effects participants;
- an unforeseen event occurs that may affect the ethical acceptability of the project.

Yours sincerely,

Hendryk Flaegel

on behalf of

Human Ethics Low Risk Panel
Research Development and Support
human.researchethics@flinders.edu.au

Flinders University
Sturt Road, Bedford Park, South Australia, 5042
GPO Box 2100, Adelaide, South Australia, 5001

http://www.flinders.edu.au/research/researcher-support/ebi/human-ethics/human-ethics_home.cfm

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Appendix C – Gannt Chart

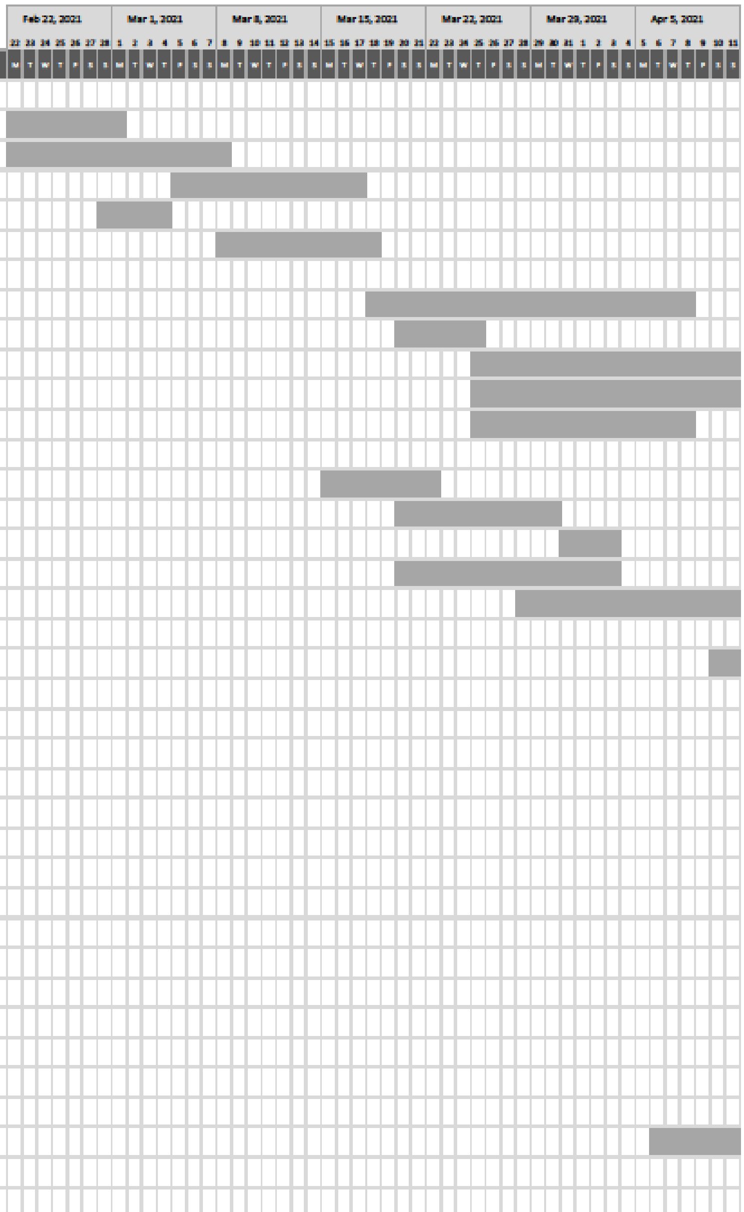
Suprascapular Nerve Block Project

Bryn McComb

Project Start: Mon, 22/2/2021

Display Week: 1

TASK	PROGRESS	START	END
Preliminary Set Up			
Determine a Supervisor	100%	22/02/21	1/03/21
Decide on Area of Study	100%	20/02/21	8/03/21
Find Supporting Information	100%	5/03/21	17/03/21
Discuss with Industry Professionals	100%	28/02/21	4/03/21
Develop Structure of Project	100%	8/03/21	18/03/21
Background Research			
Research Existing VR Training	100%	18/03/21	8/04/21
Determine VR Tools	100%	20/03/21	25/03/21
Research Possible Assets	100%	25/03/21	19/04/21
Research Into Procedure	100%	25/03/21	14/04/21
Research Benefits Gained from VR Training	100%	25/03/21	8/04/21
Planning of Project			
Develop Project Outline	100%	15/03/21	22/03/21
Develop Gannt Chart	100%	20/03/21	30/03/21
Sketch Project Concepts	100%	31/03/21	3/04/21
Create Research Proposal	100%	20/03/21	3/04/21
Plan Layout and Basic Workings of VR section of Project	100%	28/03/21	11/04/21
Develop VR Program			
Create Base World for VR Project	100%	10/04/21	20/05/21
Develop/Aquire Assets to Complete World	100%	30/04/21	4/06/21
Initial Testing of Project	100%	28/05/21	6/06/21
Error Detection and Quality Assurance	100%	3/06/21	10/06/21
Patching and Bug Fixing	100%	8/06/21	15/06/21
Additional Adjustments and Additions	100%	12/06/21	2/07/21
Final Testing	100%	2/07/21	16/07/21
Testing Project with Stakeholders			
Demonstrate Final Build with Industry Professional	100%	16/07/21	20/07/21
Test Students Prior Knowledge	Canceled	20/07/21	27/07/21
Students Use Module	100%	23/07/21	30/07/21
Interviews With Students After Module	100%	25/07/21	1/08/21
Test Students Post Knowledge	Canceled	1/08/21	8/08/21
Findings and Reports			
Evaluate Findings from Module Tests	100%	6/08/21	10/08/21
Compare Findings to Hypothesis	100%	10/08/21	14/08/21
Additional Research	100%	6/04/21	20/09/21
Write Report	100%	12/08/21	30/09/21
Present Findings	100%	11/10/21	18/10/21



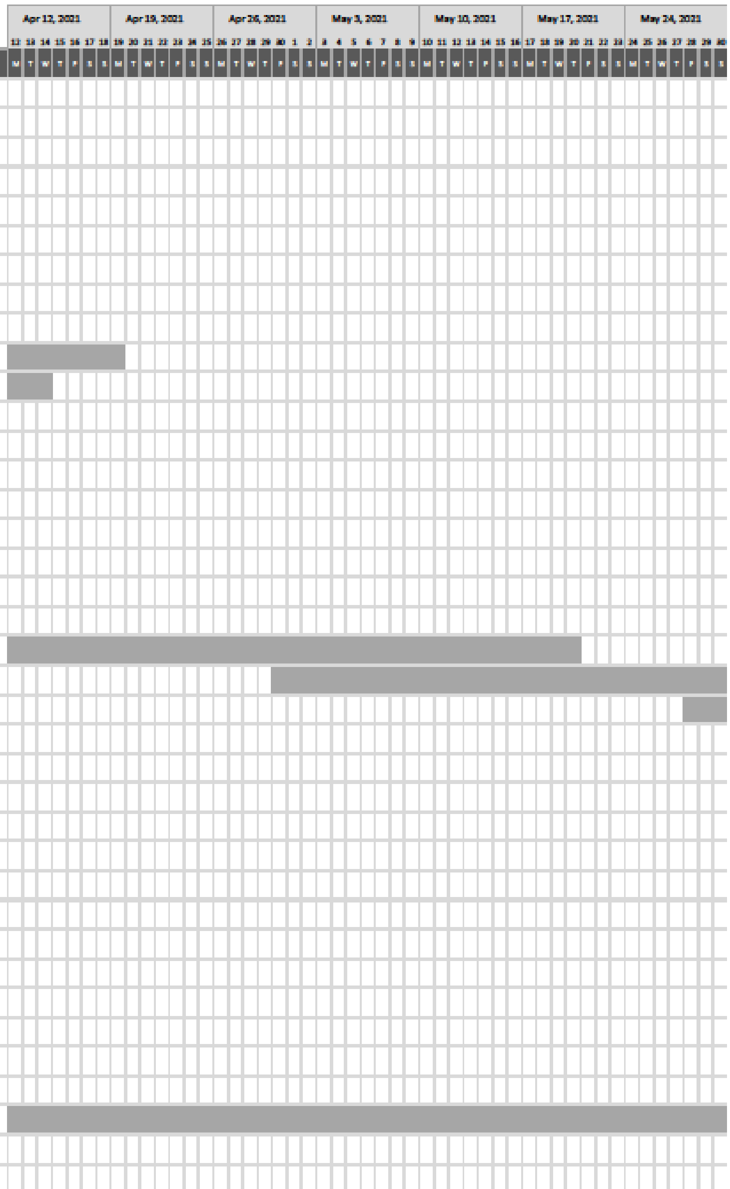
Suprascapular Nerve Block Project

Bryn McComb

Project Start: Mon, 22/2/2021

Display Week: 8

TASK	PROGRESS	START	END
Preliminary Set Up			
Determine a Supervisor	100%	22/02/21	1/03/21
Decide on Area of Study	100%	20/02/21	8/03/21
Find Supporting Information	100%	5/03/21	17/03/21
Discuss with Industry Professionals	100%	28/02/21	4/03/21
Develop Structure of Project	100%	8/03/21	18/03/21
Background Research			
Research Existing VR Training	100%	18/03/21	8/04/21
Determine VR Tools	100%	20/03/21	25/03/21
Research Possible Assets	100%	25/03/21	19/04/21
Research Into Procedure	100%	25/03/21	14/04/21
Research Benefits Gained from VR Training	100%	25/03/21	8/04/21
Planning of Project			
Develop Project Outline	100%	15/03/21	22/03/21
Develop Gannt Chart	100%	20/03/21	30/03/21
Sketch Project Concepts	100%	31/03/21	3/04/21
Create Research Proposal	100%	20/03/21	3/04/21
Plan Layout and Basic Workings of VR section of Project	100%	28/03/21	11/04/21
Develop VR Program			
Create Base World for VR Project	100%	10/04/21	20/05/21
Develop/Aquire Assets to Complete World	100%	30/04/21	4/06/21
Initial Testing of Project	100%	28/05/21	6/06/21
Error Detection and Quality Assurance	100%	3/06/21	10/06/21
Patching and Bug Fixing	100%	8/06/21	15/06/21
Additional Adjustments and Additions	100%	12/06/21	2/07/21
Final Testing	100%	2/07/21	16/07/21
Testing Project with Stakeholders			
Demonstrate Final Build with Industry Professional	100%	16/07/21	20/07/21
Test Students Prior Knowledge	Canceled	20/07/21	27/07/21
Students Use Module	100%	23/07/21	30/07/21
Interviews With Students After Module	100%	25/07/21	1/08/21
Test Students Post Knowledge	Canceled	1/08/21	8/08/21
Findings and Reports			
Evaluate Findings from Module Tests	100%	6/08/21	10/08/21
Compare Findings to Hypothesis	100%	10/08/21	14/08/21
Additional Research	100%	6/04/21	20/09/21
Write Report	100%	12/08/21	30/09/21
Present Findings	100%	11/10/21	18/10/21



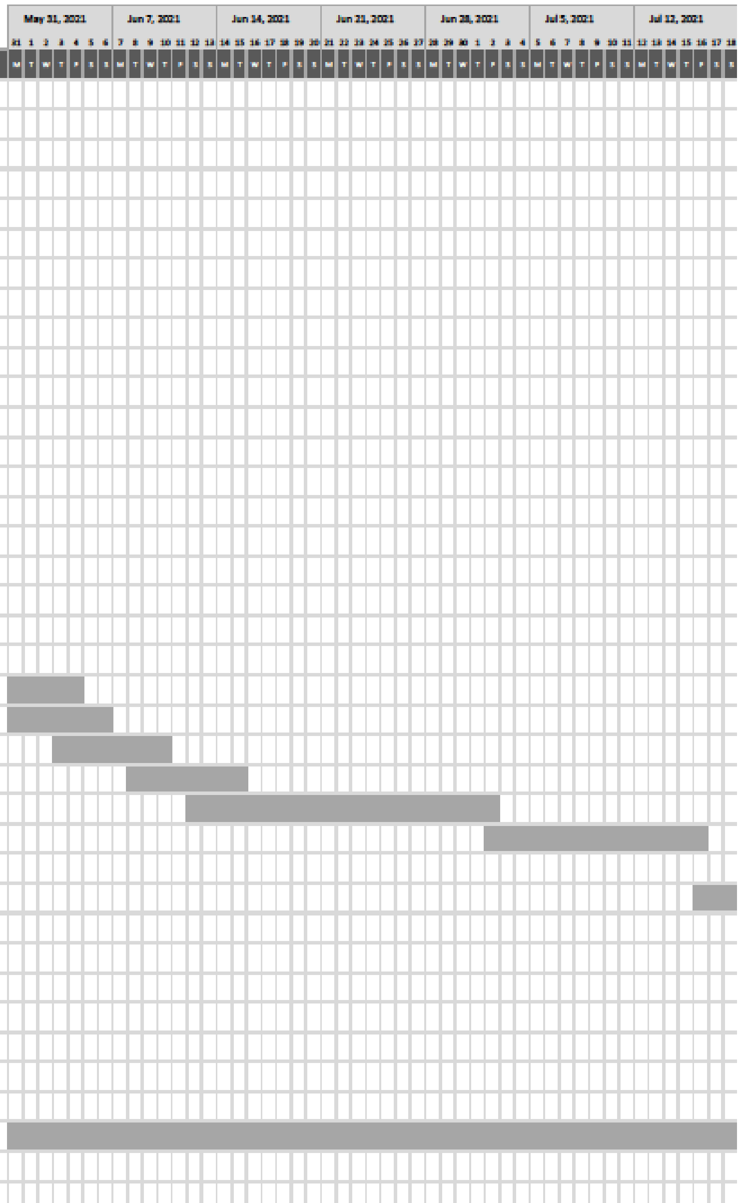
Suprascapular Nerve Block Project

Bryn McComb

Project Start: Mon, 22/2/2021

Display Week: 15

TASK	PROGRESS	START	END
Preliminary Set Up			
Determine a Supervisor	100%	22/02/21	1/03/21
Decide on Area of Study	100%	20/02/21	8/03/21
Find Supporting Information	100%	5/03/21	17/03/21
Discuss with Industry Professionals	100%	28/02/21	4/03/21
Develop Structure of Project	100%	8/03/21	18/03/21
Background Research			
Research Existing VR Training	100%	18/03/21	8/04/21
Determine VR Tools	100%	20/03/21	25/03/21
Research Possible Assets	100%	25/03/21	19/04/21
Research Into Procedure	100%	25/03/21	14/04/21
Research Benefits Gained from VR Training	100%	25/03/21	8/04/21
Planning of Project			
Develop Project Outline	100%	15/03/21	22/03/21
Develop Gannt Chart	100%	20/03/21	30/03/21
Sketch Project Concepts	100%	31/03/21	3/04/21
Create Research Proposal	100%	20/03/21	3/04/21
Plan Layout and Basic Workings of VR section of Project	100%	28/03/21	11/04/21
Develop VR Program			
Create Base World for VR Project	100%	10/04/21	20/05/21
Develop/Aquire Assets to Complete World	100%	30/04/21	4/06/21
Initial Testing of Project	100%	28/05/21	6/06/21
Error Detection and Quality Assurance	100%	3/06/21	10/06/21
Patching and Bug Fixing	100%	8/06/21	15/06/21
Additional Adjustments and Additions	100%	12/06/21	2/07/21
Final Testing	100%	2/07/21	16/07/21
Testing Project with Stakeholders			
Demonstrate Final Build with Industry Professional	100%	16/07/21	20/07/21
Test Students Prior Knowledge	Canceled	20/07/21	27/07/21
Students Use Module	100%	23/07/21	30/07/21
Interviews With Students After Module	100%	25/07/21	1/08/21
Test Students Post Knowledge	Canceled	1/08/21	8/08/21
Findings and Reports			
Evaluate Findings from Module Tests	100%	6/08/21	10/08/21
Compare Findings to Hypothesis	100%	10/08/21	14/08/21
Additional Research	100%	6/04/21	20/09/21
Write Report	100%	12/08/21	30/09/21
Present Findings	100%	11/10/21	18/10/21



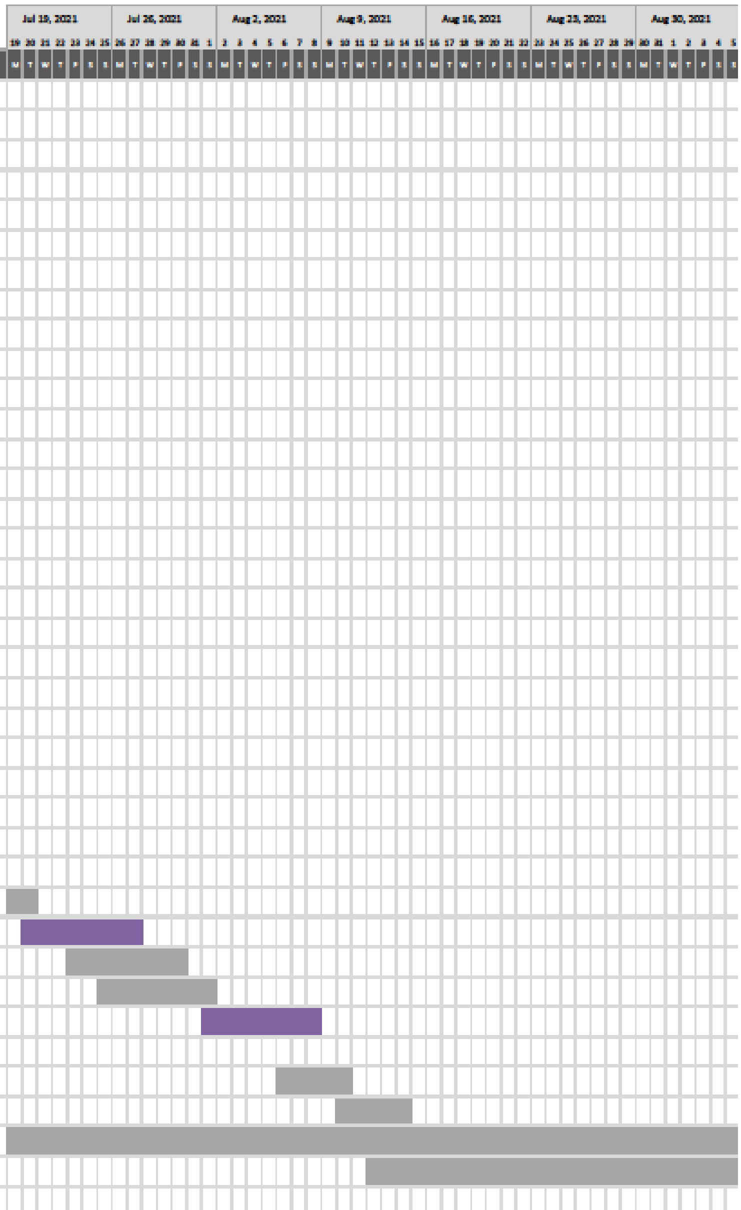
Suprascapular Nerve Block Project

Bryn McComb

Project Start: Mon, 22/2/2021

Display Week: 22

TASK	PROGRESS	START	END
Preliminary Set Up			
Determine a Supervisor	100%	22/02/21	1/03/21
Decide on Area of Study	100%	20/02/21	8/03/21
Find Supporting Information	100%	5/03/21	17/03/21
Discuss with Industry Professionals	100%	28/02/21	4/03/21
Develop Structure of Project	100%	8/03/21	18/03/21
Background Research			
Research Existing VR Training	100%	18/03/21	8/04/21
Determine VR Tools	100%	20/03/21	25/03/21
Research Possible Assets	100%	25/03/21	19/04/21
Research Into Procedure	100%	25/03/21	14/04/21
Research Benefits Gained from VR Training	100%	25/03/21	8/04/21
Planning of Project			
Develop Project Outline	100%	15/03/21	22/03/21
Develop Gannt Chart	100%	20/03/21	30/03/21
Sketch Project Concepts	100%	31/03/21	3/04/21
Create Research Proposal	100%	20/03/21	3/04/21
Plan Layout and Basic Workings of VR section of Project	100%	28/03/21	11/04/21
Develop VR Program			
Create Base World for VR Project	100%	10/04/21	20/05/21
Develop/Aquire Assets to Complete World	100%	30/04/21	4/06/21
Initial Testing of Project	100%	28/05/21	6/06/21
Error Detection and Quality Assurance	100%	3/06/21	10/06/21
Patching and Bug Fixing	100%	8/06/21	15/06/21
Additional Adjustments and Additions	100%	12/06/21	3/07/21
Final Testing	100%	2/07/21	16/07/21
Testing Project with Stakeholders			
Demonstrate Final Build with Industry Professional	100%	16/07/21	20/07/21
Test Students Prior Knowledge	Canceled	20/07/21	27/07/21
Students Use Module	100%	23/07/21	30/07/21
Interviews With Students After Module	100%	25/07/21	1/08/21
Test Students Post Knowledge	Canceled	1/08/21	8/08/21
Findings and Reports			
Evaluate Findings from Module Tests	100%	6/08/21	10/08/21
Compare Findings to Hypothesis	100%	10/08/21	14/08/21
Additional Research	100%	6/04/21	20/09/21
Write Report	100%	12/08/21	30/09/21
Present Findings	100%	11/10/21	18/10/21



Suprascapular Nerve Block Project

Bryn McComb

Project Start: Mon, 22/2/2021

Display Week: 29

TASK	PROGRESS	START	END
Preliminary Set Up			
Determine a Supervisor	100%	22/02/21	1/03/21
Decide on Area of Study	100%	20/02/21	8/03/21
Find Supporting Information	100%	5/03/21	17/03/21
Discuss with Industry Professionals	100%	28/02/21	4/03/21
Develop Structure of Project	100%	8/03/21	18/03/21
Background Research			
Research Existing VR Training	100%	18/03/21	8/04/21
Determine VR Tools	100%	20/03/21	25/03/21
Research Possible Assets	100%	25/03/21	19/04/21
Research Into Procedure	100%	25/03/21	14/04/21
Research Benefits Gained from VR Training	100%	25/03/21	8/04/21
Planning of Project			
Develop Project Outline	100%	15/03/21	22/03/21
Develop Gannt Chart	100%	20/03/21	30/03/21
Sketch Project Concepts	100%	31/03/21	3/04/21
Create Research Proposal	100%	20/03/21	3/04/21
Plan Layout and Basic Workings of VR section of Project	100%	28/03/21	11/04/21
Develop VR Program			
Create Base World for VR Project	100%	10/04/21	20/05/21
Develop/Aquire Assets to Complete World	100%	30/04/21	4/06/21
Initial Testing of Project	100%	28/05/21	6/06/21
Error Detection and Quality Assurance	100%	3/06/21	10/06/21
Patching and Bug Fixing	100%	8/06/21	15/06/21
Additional Adjustments and Additions	100%	12/06/21	2/07/21
Final Testing	100%	2/07/21	16/07/21
Testing Project with Stakeholders			
Demonstrate Final Build with Industry Professional	100%	16/07/21	20/07/21
Test Students Prior Knowledge	Canceled	20/07/21	27/07/21
Students Use Module	100%	23/07/21	30/07/21
Interviews With Students After Module	100%	25/07/21	1/08/21
Test Students Post Knowledge	Canceled	1/08/21	8/08/21
Findings and Reports			
Evaluate Findings from Module Tests	100%	6/08/21	10/08/21
Compare Findings to Hypothesis	100%	10/08/21	14/08/21
Additional Research	100%	6/04/21	20/09/21
Write Report	100%	12/08/21	30/09/21
Present Findings	100%	11/10/21	18/10/21

Appendix D – Bibliography

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