

2026-27 HIVE Summer Internship Project

A virtual reality reaching game for measuring shoulder range of motion and movement quality

Primary Academic Supervisor

Dr. Steve Tidman

Project Background

Shoulder pain is among the most common musculoskeletal presentations, and procedures such as rotator cuff repair and shoulder arthroplasty are performed in increasing numbers to restore pain free movement. Recovery is routinely evaluated using handheld goniometry and patient reported outcome measures. Both quantify end range position or perceived function, and neither describes the quality of the movement used to arrive there.

Movement quality is measurable. Smoothness metrics, including spectral arc length and log dimensionless jerk, discriminate the affected from the unaffected limb in patients with rotator cuff tears (Mancini et al. 2026), and reaching kinematics differ between anatomic and reverse shoulder arthroplasty. Experimental shoulder pain and induced muscle fatigue both alter trunk and shoulder kinematics during reaching in a virtual environment. These metrics are derived from optical motion capture, which restricts their use to the laboratory.

Consumer virtual reality headsets track head and hand position at high sampling rates and low cost. Virtual goniometry performed on a headset shows excellent system reliability for shoulder flexion and scaption (ICC 0.99), although it overestimates angle relative to inclinometry by approximately 11 degrees (Dejaco et al. 2023). Game based virtual reality has also been delivered as a shoulder rehabilitation intervention after rotator cuff repair. However, whether a game-based reaching task can function as a measurement instrument, returning range of motion and movement quality, remains untested.

This project will develop and pilot that instrument. Balloon targets will be positioned at defined angles of shoulder elevation, abduction and horizontal adduction, scaled to individual arm length, and be ‘popped’ with a virtual sword to score points. The headset will record the hand trajectory throughout play. Range of motion will be derived from the angles at which targets are intercepted, and efficiency, trajectory and speed is recorded.

Project Description, Expected Outputs, Possible Stretch Goals

The aim of this project is to develop and pilot a virtual reality reaching game that quantifies shoulder range of motion and movement quality in a single five-minute session, and to visualise the output in a form a clinician can interpret. The student will build the game in Unity for the Meta Quest 3, log head and hand position throughout play, derive clinical metrics from those traces, and pilot the assessment in healthy adults.

Expected outputs:

- A playable virtual reality game incorporating calibration for height and arm length, balloon targets positioned at defined shoulder angles, and scaled difficulty.
- A logging pipeline exporting timestamped head and hand position at the headset frame rate.
- An analysis script returning peak elevation, abduction and horizontal adduction, path length ratio (movement efficiency), peak and mean hand velocity, time to peak velocity, and smoothness (spectral arc length, log dimensionless jerk).
- Visualisation outputs comprising a three-dimensional reach envelope, hand trajectory plots, and a single page participant summary.
- Pilot data from 10 to 15 healthy adults, including a repeated session for test-retest estimates.
- Final report and live demonstration.

Stretch goals:

- Comparison of peak angles against 3D motion capture.
- Between limb comparison and an automated limb symmetry index.
- A multi participant visualisation for the HIVE tiled display presenting trajectory clouds and reach volumes.
- Real time compensation feedback derived from headset and trunk displacement.

Links to background reading and any relevant recent work in the field

- Dejaco et al. (2023). Concurrent validity and reliability of virtual reality to measure shoulder flexion and scaption range of motion. Physiotherapy.
<https://www.sciencedirect.com/science/article/pii/S0031940623000330>
- Mancini et al. (2026). Movement smoothness matters: the missing piece in the functional assessment of rotator cuff patients. Journal of Experimental Orthopaedics.
<https://pmc.ncbi.nlm.nih.gov/articles/PMC12954642/>
- Virtual reality for shoulder rehabilitation: accuracy evaluation of Oculus Quest 2. Sensors (2022). <https://doi.org/10.3390/s22155511>
- Performance evaluation of an immersive virtual reality application for rehabilitation after arthroscopic rotator cuff repair.
<https://pmc.ncbi.nlm.nih.gov/articles/PMC10668954/>
- Fatigue influences trunk and shoulder kinematics during an upper limb reaching task in a virtual reality environment.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8031876/>
- Measurement properties of movement smoothness metrics for upper limb reaching movements.
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11134951/>

What type of visualisation will the student develop or produce?

An immersive virtual reality experience built in Unity for the Meta Quest 3, together with data visualisation generated from play. Three components are planned:

- the game environment, in which coins are positioned within a calibrated reach space;
- participant level three-dimensional reach envelopes and hand trajectory renders; and
- a clinician facing summary combining angle, efficiency and speed.

Trajectory clouds across multiple participants will be rendered for the HIVE tiled display.

How will the visualisation contribute to your research outcomes?

Existing shoulder outcome measures quantify end range and provide no information on the movement used to reach it. Rendering the hand trajectory makes movement quality visible and interpretable, which is a precondition for clinical use. The pilot will establish whether the game returns stable and physiologically sensible measures in healthy adults, which is the step required before ethics approval is sought to assess patients before and after shoulder surgery.

If the project is successful, where would you consider publishing the results?

The instrument development and pilot reliability work is suited to JSES International or the Journal of Shoulder and Elbow Surgery. The development and usability components are suited to Games for Health Journal or JMIR Serious Games. Kinematic analyses would be submitted to Gait and Posture or the Journal of Biomechanics. Findings will be presented at the Exercise and Sports Science Australia Research to Practice conference and at the Australian Shoulder and Elbow Society meeting.

Draft Project Timeline:

Week 1

Nov 16 - Full day HIVE induction

Nov 17 - Area and Project Induction with Primary supervisor

Develop project plan with HIVE and academic team

Literature and relevant project review

Project Familiarisation

Week 2

The Unity and Meta Quest 3 development environment will be established and a build deployed to the headset. A basic reach scene will be constructed to learn the toolchain. Coin target positions will be defined with the supervisors as a function of arm length and the shoulder angles of interest (elevation, abduction, horizontal adduction).

Milestone 1: a build running on the headset.

Week 3

The core game loop will be built, including a calibration routine capturing height, arm length and a seated reference position. Coin spawning at the defined angles, hit detection, scoring and a session structure with a fixed number of reaches per direction will be implemented.

Week 4

Data logging will be implemented, with timestamped head and hand position written at the headset frame rate and exported at the end of each session. Sampling rate will be verified and dropped frames quantified.

Milestone 2: a playable game producing a clean data file.

Week 5

The analysis will be written in Python or R and will return peak angle by plane, path length ratio, peak and mean velocity, time to peak velocity, and smoothness (spectral arc length and log dimensionless jerk). Output will be verified against manually checked trials, followed by an internal demonstration to the supervisory team.

Week 6

Usability testing will be conducted with laboratory volunteers. Coin placement, difficulty and in game instruction will be revised in response to that testing, and the protocol will then be locked for the pilot.

Week 7

Pilot data will be collected on researcher team members, with a repeat session in a subset to provide test-retest estimates

Week 8

The pilot data will be analysed and the visualisation outputs produced, comprising the three dimensional reach envelope, trajectory plots, the single page participant summary, and the multi participant trajectory cloud for the tiled display.

Milestone 3: complete visualisation set.

Week 9

Focus on report writing and presentation (including demo) preparation

Week 10

Focus on report writing and presentation (including demo) preparation

5th Feb Final Showcase Day and final report due

Student Experience and Supervision:

How often will you meet with the student over the 10-week period?

A scheduled one-hour meeting will be held each week with the primary supervisor, and a fortnightly meeting with both supervisors and the assigned HIVE staff member. The student will be seated in the same area as the primary supervisor, so informal daily catch-up.

Your work desk location and the location of student desk

Steve Tidman - Building 4, Office 264.

Student Attributes:**Please indicate any preference for student's academic discipline or field of study**

Computer Science, software engineering, or games design and interactive media. A biomedical engineering or exercise and sport science student with prior Unity experience would also be well suited to the project.

What competencies are required to start this project

Beginner - 2D art/editing

Beginner - 3D modelling software (Blender, 3ds Max)

Beginner - AI Integrations (build tools to assist with custom workflows)

Beginner - comfortable testing prototypes on people

Intermediate - Game engine development (Unity, Unreal. Godot, etc.)

Intermediate - Virtual Reality Development (rendering pipelines, scene content design, interaction)

Intermediate - Data structures, analytics, statistical modelling

Intermediate - scripting in Python or R

Do you have any other student attributes you think are important to the project?

An interest in human movement is more important than any clinical background. The instrument is intended for use with patients recovering from shoulder surgery, so a willingness to test early versions with researchers and revise them in response to what that testing shows is important. No prior anatomy knowledge is required, and the relevant content will be taught during the first fortnight.