INTERACTIVE FULL BODY EXERCISE EXPERIENCE

FOR PEOPLE AFFECTED WITH ANKYLOSING

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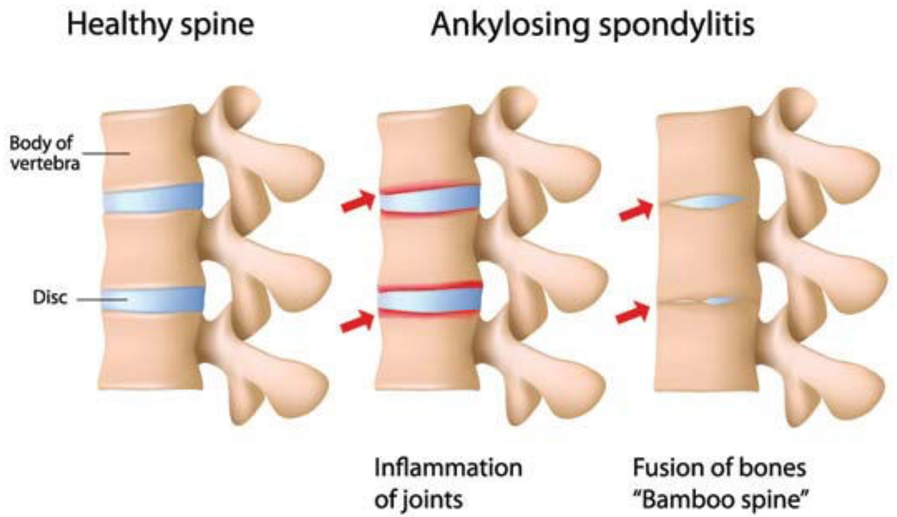
ANKYLOSING SPONDYLITIS (AS)

DEFINITION

Ankylose - become stiffened or united.

- Inflammatory rheumatic disease.
- Mainly affects the axial skeleton.
- Joint margins gradually ossify.



CAUSE

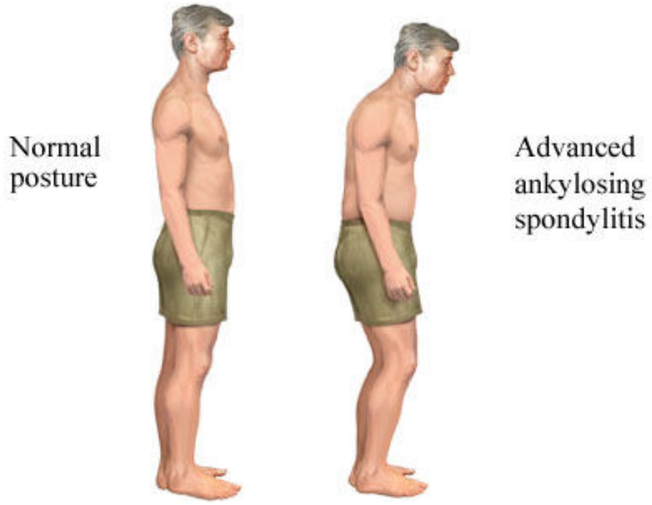
- Prevalence of HLA-B27 (Not a confirmatory test for AS) and / or TNF- α.
- Specific bacterial agent Klebsiella, which has an established relationship with HLA-B27.

ANKYLOSING SPONDYLITIS (AS)

SYMPTOMS

Develops in late teens / early adulthood.

- Low back pain / tenderness / stiffness.
- Worse at night or in the morning, eased by activity/ exercise.
- Muscle spasm, fatigue.
- Reduced spinal mobility and reduced chest expansion.
- Uveitis, inflammation of uvea (layer between retina and cornea).
- ‘Bamboo Spine’ appearance.



ANKYLOSING SPONDYLITIS (AS)

CLINICAL TREATMENTS

- Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)
- TNF – α Inhibitors
- Analgesics
- Corticosteroids
- Disease Modifying Anti-Rheumatic Drugs (DMARDs)

SIDE-EFFECTS

- Increased risk of GI bleeding and perforation
- Kidney failure , liver failure
- Heart failure, Increased frequency of infections e.g. TB, Cancer
- Tolerance, respiratory depression, sedation
- Low bone marrow count

Aggravating Factors

- Humid / Cold Weather
- Poor Sleep
- Physical Inactivity
- Anxiety / Stress
- Jerks

Relieving Factors

- Warm Weather
- Moderate physical activity
- Local heat
- Starch free diet
- Mental relaxation

PRIMARY RESEARCH

- Initial primary research to understand role of exercises in AS.
- Understanding the level of motivation among patients to exercise.

PATIENTS

4 patients

Extreme : 2 patients

Moderate : 1 patient

Low : 1 patient

DOCTORS

3 doctors, 1 physiotherapist

- Rheumatologist
- Anaesthetist
- Psychiatrist

PRIMARY RESEARCH

PATIENTS - INSIGHTS

- Exercise, diet only remedies with no side-effects.
- Patients lack guidance and start immunosuppressant drugs.
- Limited access to information.
- Reduced range of motion hindrance to daily activities.
- Pain increases due to inactivity.
- Lack of motivation and time to exercise daily.
- Depression, deteriorating personal and professional life.
- Evidence of exercises improving condition of patients.

Exercise is a mandate for AS patients

Lack of motivation one of the major problems

PRIMARY RESEARCH

DOCTORS - INSIGHTS

- More inclined towards pain management.
- Tend to ignore long time side effects.
- Less trust on exercise and diet, treats these as an adjunct to medicine.
- Try to convince patients that medicine is the ultimate option.
- Patients can become victims of drug abuse to get remedy from excruciating pain.
- Patients have physical limitations, depression and emotional status.

PRIMARY RESEARCH

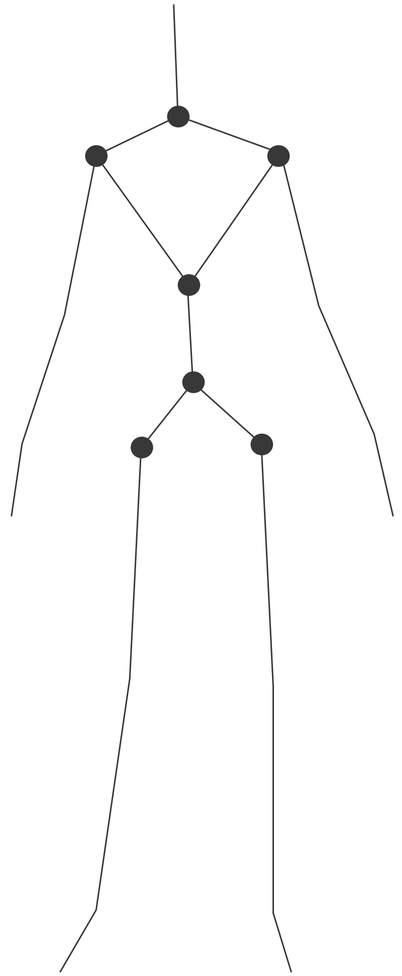
PHYSIOTHERAPIST - SUGGESTIONS AND INSIGHTS

- Maintaining posture is very important apart from exercising.
- Exercises should follow the FITT (Frequency, Intensity, Time, Type) principle.
- The exercises should be in the order of Posture, Flexibility, Respiratory, Aerobic, Strengthening.
- 30 minutes of daily exercise prescribed, 10 minutes each phase, 3 times a day.
- Same exercise can be done in different postures (Example : lying down can be replaced by crawling).
- Keeping all the joints active is very important as other joints might get affected as well.
- Patients can come up with trick movements.
- Avoid contact sports, jerks.
- Need to be careful about brittle bones in advanced stages.

EXERCISES

EXERCISES SUGGESTED

- Neck movements in sitting/standing - forward, backward, sideways, and rotations.
- Trunk movements in standing with feel apart - forward, backward, sideways and rotations.
- Breathing exercises with shoulder movements.
- Bridging while standing for back and hip, wall or chair as support.
- Cat - camel exercises for lumbar region in quadruped (crawling position).
- Hip rotations while lying on back - knees have to be bent for this exercise.
- Lying on stomach and lift each hand up from the shoulder and each leg up from hip.



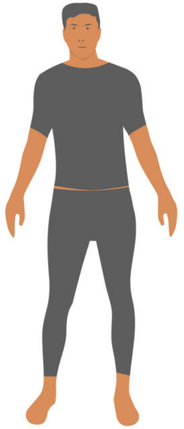
EXERCISES

Breathing Exercise
(chest and shoulder)

Respiratory

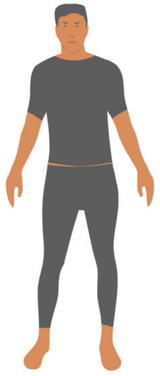
Bridging in
standing position
(hip)

Strengthening



Neck rotation
(Neck)

Flexibility



Trunk Exercise
(Lumbar and sacroiliac)

Flexibility, Aerobic

Cat-camel quadruped
(Spine)

Flexibility

SECONDARY RESEARCH

Exploring existing solutions to make people exercise

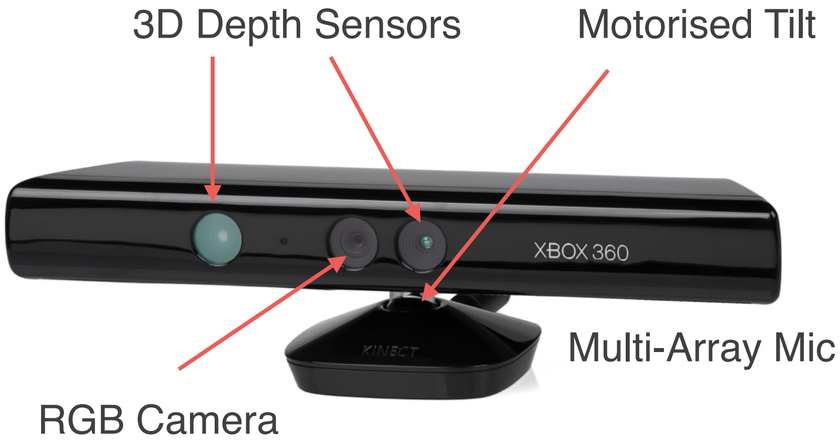
- Games, a known medium to motivate people exercise, gamifying exercises.
- ‘Exergames’, facilitates active lifestyle, motor rehabilitation in patients.
- Exergames are either instructor based, simulation of outdoor games, virtual dance classes or gameful systems.
- Synchronous and asynchronous monitoring of physical activity well practiced trend in exergames.
- Mini game is an affordable and scalable substitute.
- Audio story-telling techniques for exercises to provide a prompt feedback to player’s activity.
- Modular approach where the control (hardware) and configuration layers are separate from the game.
- Virtual / Augmented reality used as a medium to simulate real life scenarios.

TECHNOLOGY

Motion Sensors - Kinect widely used, hands free, economic, standalone developer support, open source libraries.

Virtual Reality - Useful for upper body exercises, patients might fall while exercising in standing position.

Device	Price ₹	Controller	Usage
Kinect (Xbox 360)	7000	No separate console	Can be used as a standalone sensor
Sony Playstation eye (PS3)	1,498 with playstation (16,200)	Separate controller with accelerometer, gyroscope	No depth in playstation eye, cannot be used without Playstation console.
Nintendo Wii	19,890	nunchuck with accelerometer, gyroscope	Plugins need to be bought separately to use it as a standalone device



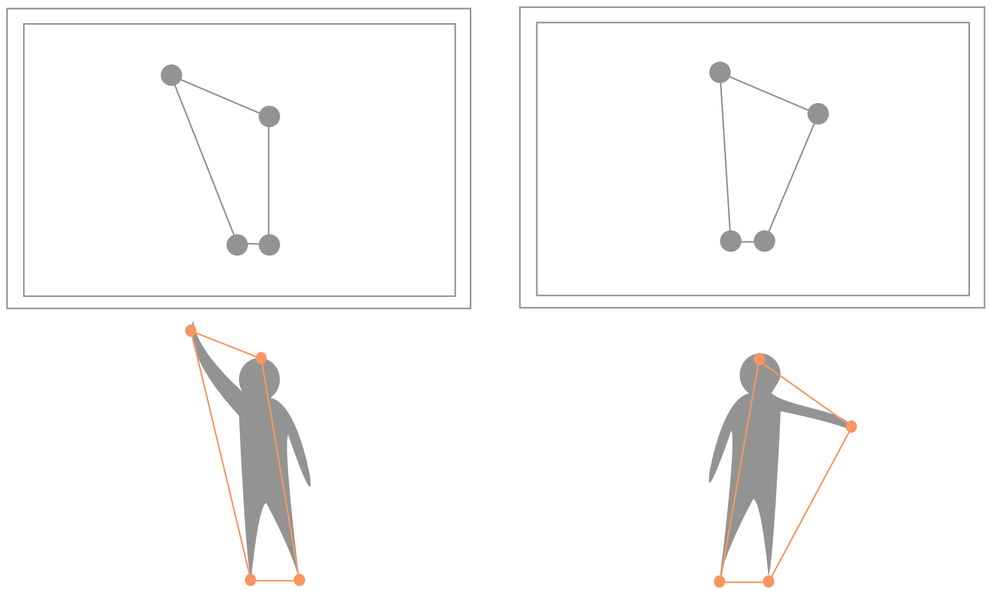
Kinect XBOX 360

VR Headset with Bluetooth controller

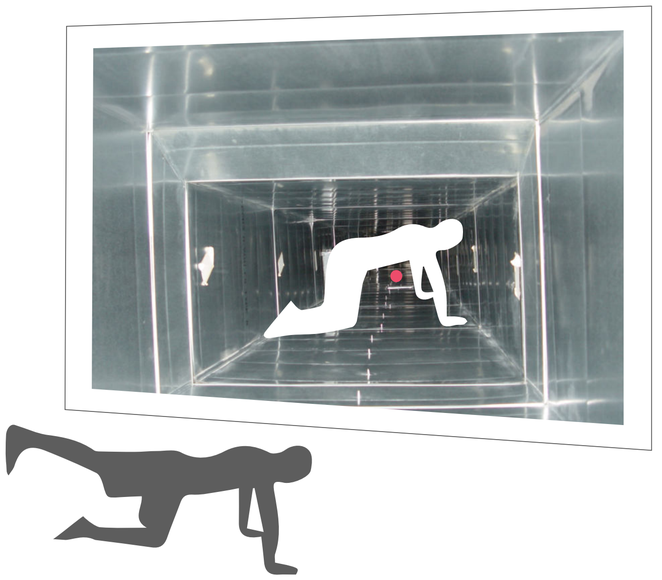
INITIAL DESIGN IDEAS

Objective : Embedding selected exercises into games

- Align with some highlighted points on the screen
- Matching embedded posture
- Exercises were mapped into micro-tasks



- Gameplay with narrative
- Marching, crawling to advance through the game
- Levels based on difficulty of exercises
- Strategic breathing breaks, repetitions embedded



INITIAL CONCERNS AND PRE-PILOT FEEDBACK

INITIAL CONCERNS

- Possibilities of ambiguous, open-ended interactions.
- Intentional or accidental trick movements.
- Repeat play possibilities.
- Performing the exercises with no hardware access.

EMERGING QUESTIONS

- What problems are games solving?
- Is game the right medium?
- Will motivated patients be interested in playing games?

INSIGHTS

- Games solve only motivation issue.
- Jerks through open ended interactions
- Embellishment for motivated patients.
- Incapacitating patients during absence of hardware.

EXPERT FEEDBACK

Can the games be built on top of existing solutions?

Lack of existing commercial applications as different therapies have its own specific set of requirements.

Existing solutions either focus on rehabilitation or generic active lifestyle.

Exercises are mandate, not an active lifestyle promoting aspect for AS patients.

AS patients should not stop exercising even after the complete range of motion is revived.

Lack of physical activity detrimental to patients, leading to a rapid fusion of joints.

What features can be reused from the current solutions?

Recent frameworks designed can be extended to cater to specific therapeutical needs.

Separating exercise, control, hardware and game layers, reusing elements like remote supervision.

SOLUTION PERSPECTIVES

IDENTIFIED ISSUES

- Accessibility - lack of physiotherapists in suburbs and villages.
- Affordability - daily physiotherapist supervision is a costly service.
- Flexibility - time of the day, duration, aligning with physiotherapist’s schedule.
- Motivation - patients drop out after the exacerbation period is over.

MODIFIED DESIGN IDEAS

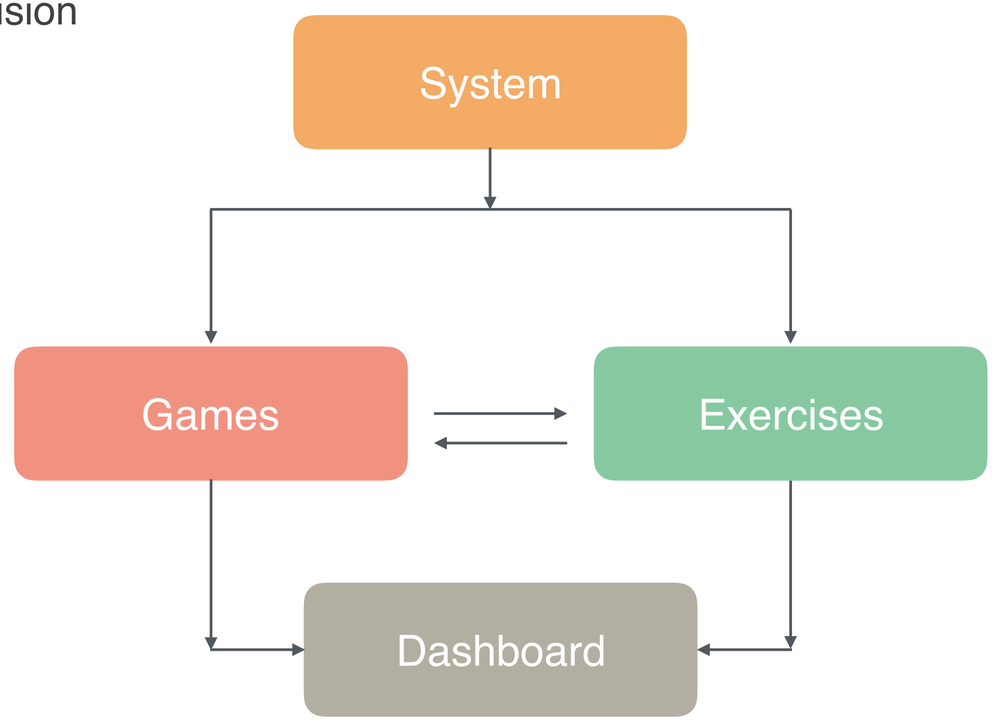
Exercise Regime

demonstration + intrinsic motivation + tracking + feedback + remote supervision

Game

extrinsic motivation + tracking + remote supervision

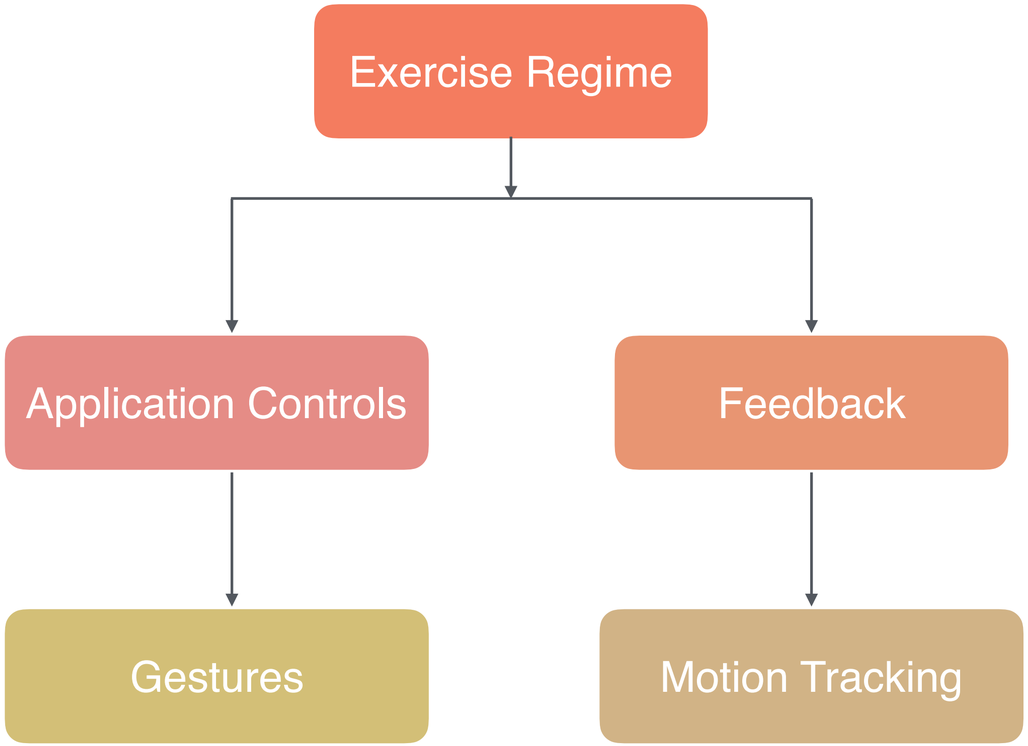
SYSTEM DESIGN



EXERCISE REGIME FEATURES

FEATURES

- Feedback and tracking
- Repeat and Redo
- Disease knowledge
- Intrinsic Motivation and gamifying exercises
- Switch between exercise and games
- Social Media integration
- Remote supervision

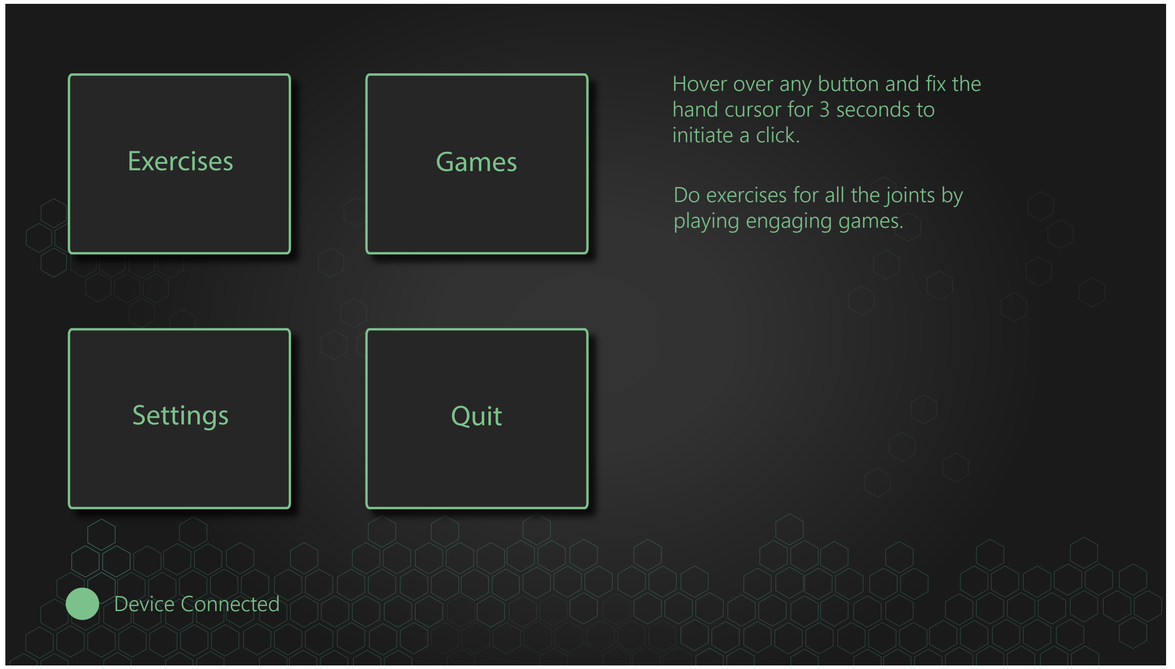


EXERCISE REGIME APPLICATION CONTROLS

GESTURE CATEGORISATION

- Patient — easy & difficult (ability/disease), intuitive & non-intuitive
- Sensor — easily trackable & difficult to track

- Click difficult, hand cursor deflects more on screen
- The controls should be intuitive
- Patients should have the ability to perform the gestures



EXERCISE REGIME APPLICATION CONTROLS

GESTURES

Easy Gestures (intuitive)

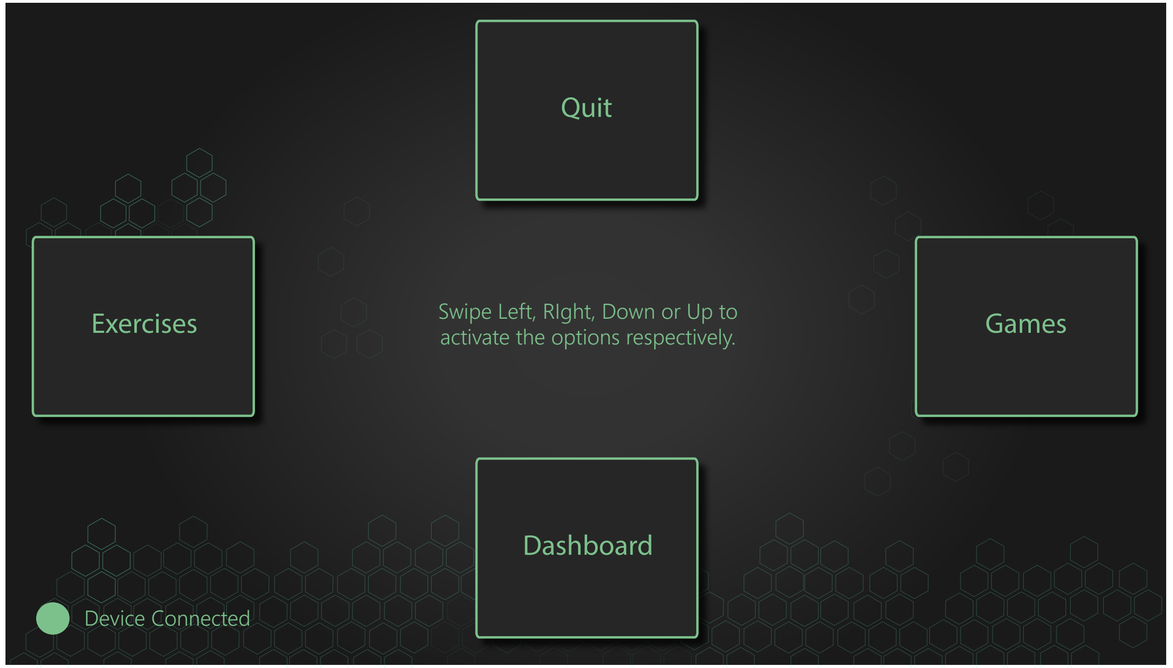
- Raise Left Hand
- Raise Right Hand
- Wave
- T pose
- Psi pose
- Swipe (U, D)

Difficult Gestures (non-intuitive)

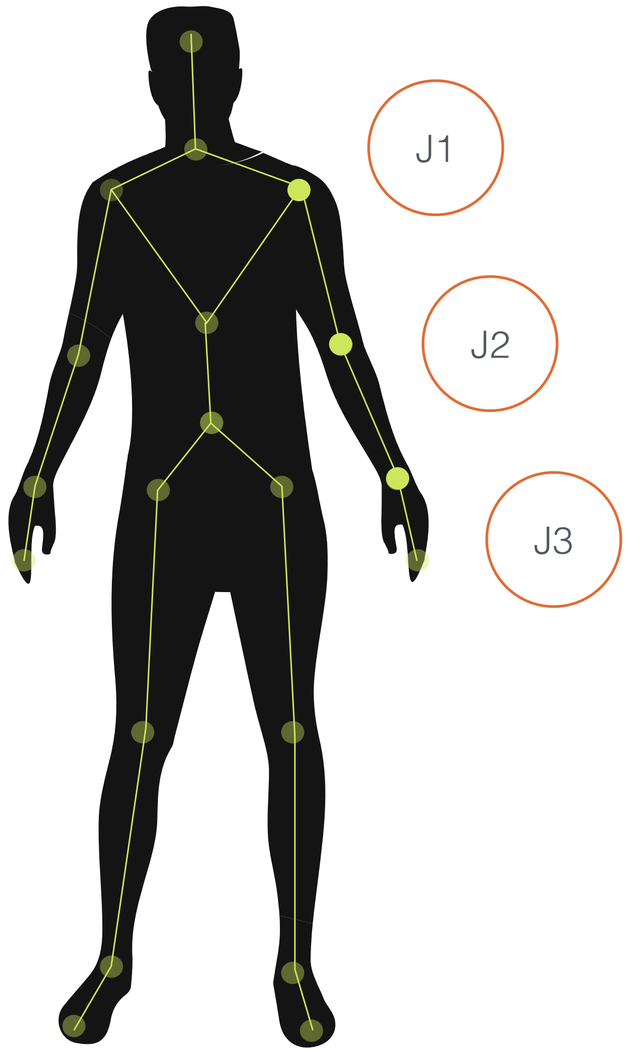
- Swipe (L, R)
- Zoom in
- Zoom out
- Wheel
- Stop
- Push
- Pull

Patient difficult

Patient easy



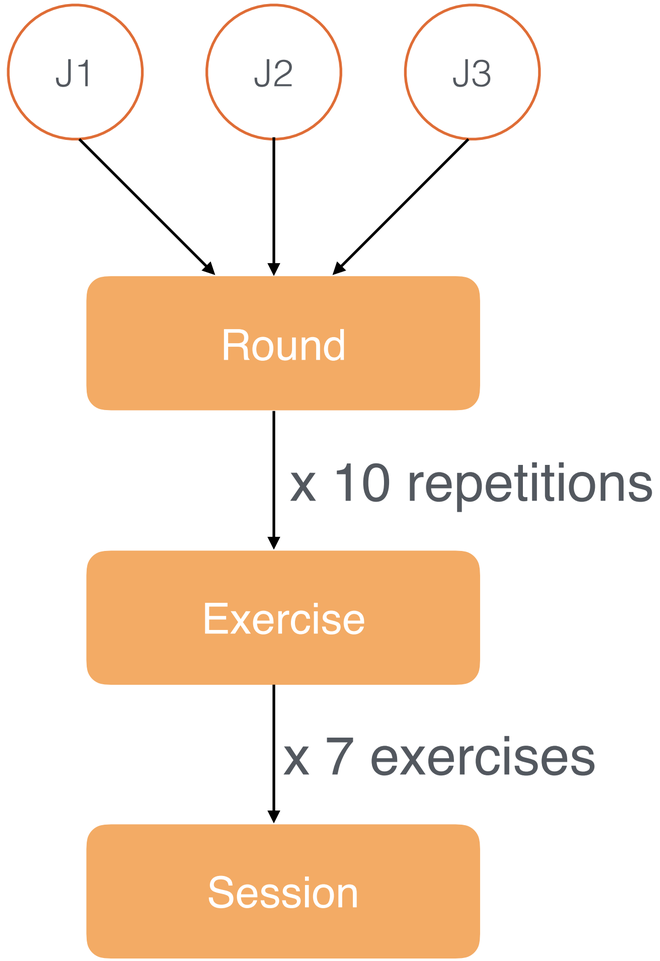
EXERCISE REGIME FEEDBACK AND TRACKING



- Joint Tracking
- Immediate Feedback

- Round Tracking
- Exercise Tracking
- Exercise Feedback

- Session Feedback



EXERCISE REGIME FEEDBACK CALCULATION

FEEDBACK CALCULATION

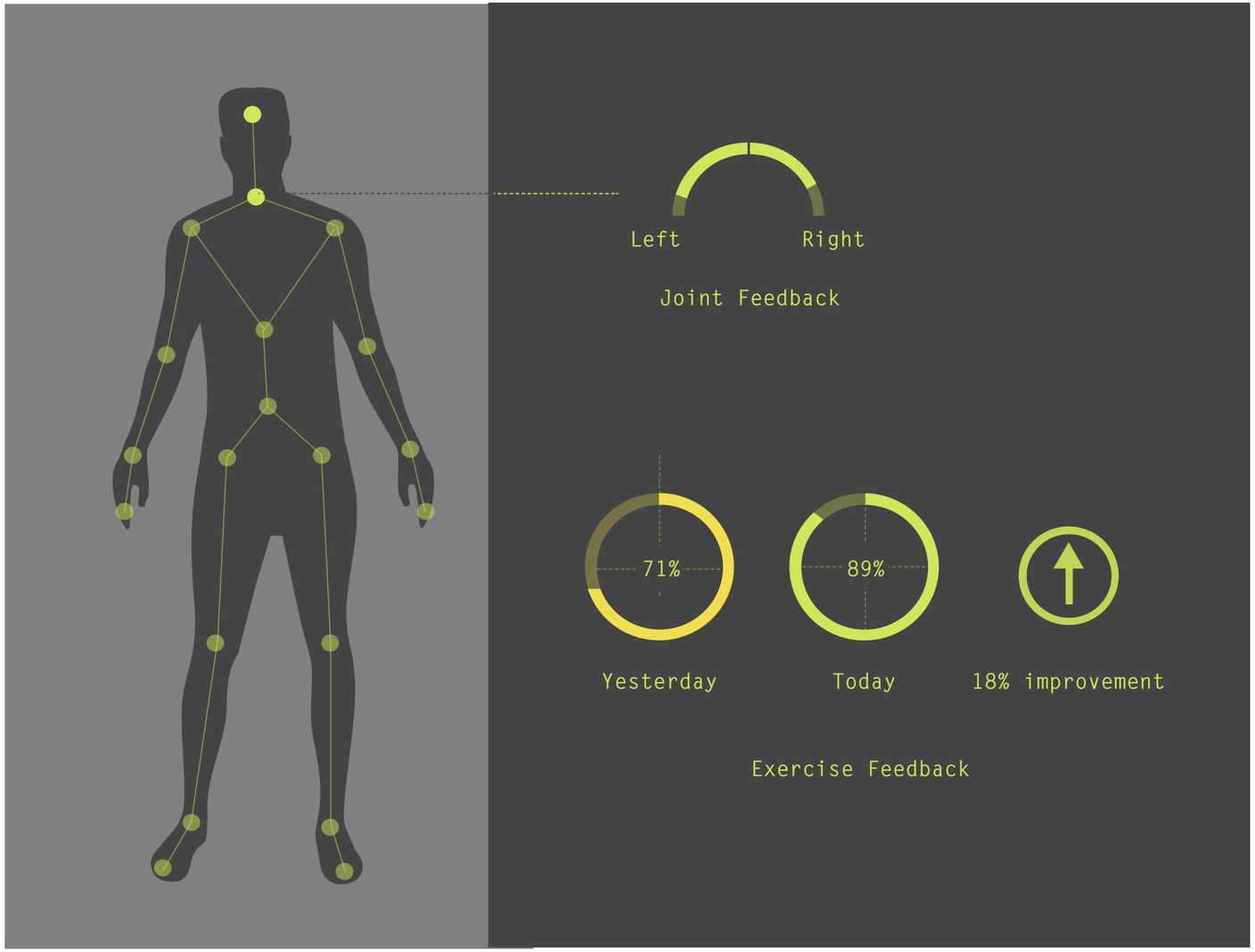
$$r = \frac{\sum_{i=1}^{n} w_i j_i}{\sum_{i=1}^{n} w_i}$$

$$e = \frac{\sum_{i=1}^{n} r_i}{n}$$

$$s = \frac{\sum_{i=1}^{n_1} e_i}{n_1}$$

Concerns of immediate feedback

- Immediate Feedback can be too intrusive.
- Poor performance can demotivate patients.
- Round feedback can distract patients.



EXERCISE REGIME FEATURES

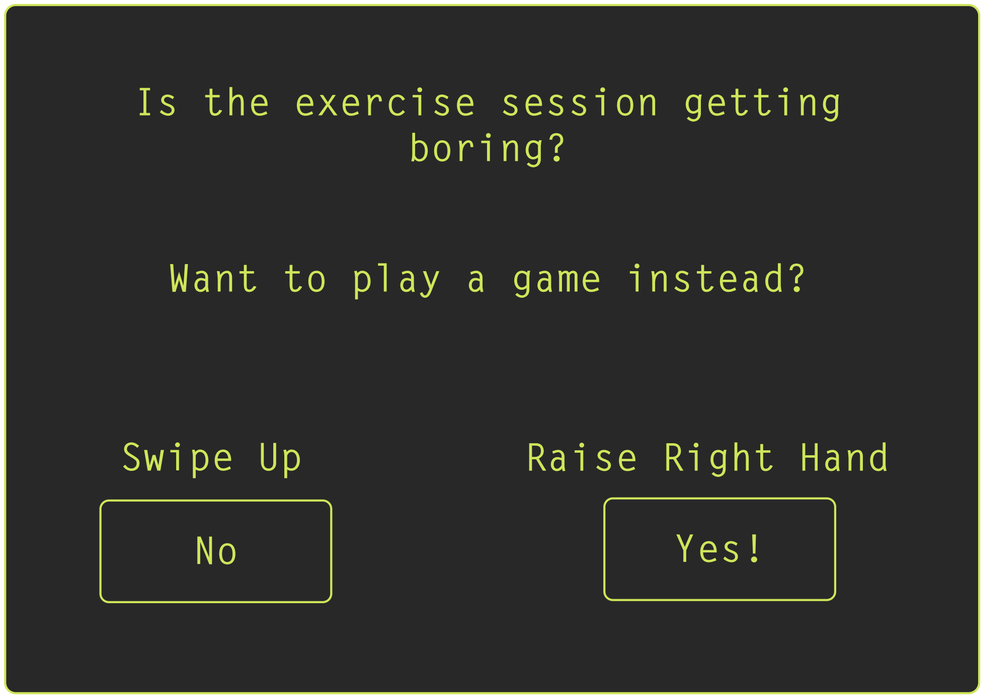
- Exercise Completion Feedback
- Easy gestures for repeat / re-do

- Highlighting the joints involved with in an exercise.
- Skip option during exacerbation.
- Differentiating between pain due to stiffness and exacerbation.

EXERCISE REGIME FEATURES

- Improved range of motion notification
- Feedback after each exercise

- Motion and time track (idle time and duration)
- Preventing quitting between session



EXERCISE REGIME FEATURES

- Clinical treatment options
- Diet modification information
- Other patient experience (linking with social media)
- Triggered while a screen is loading to save time

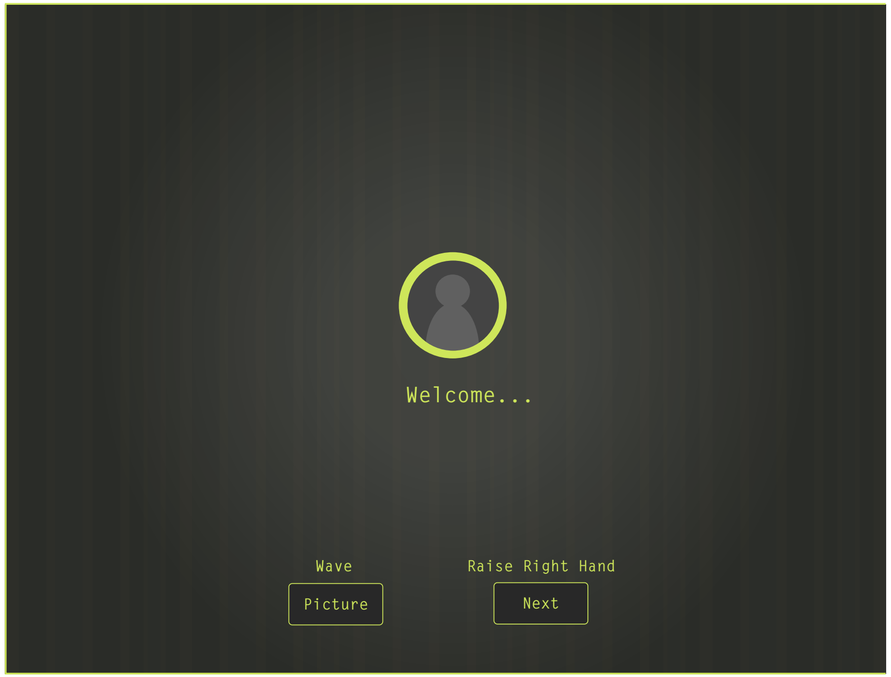
Tip of the Day

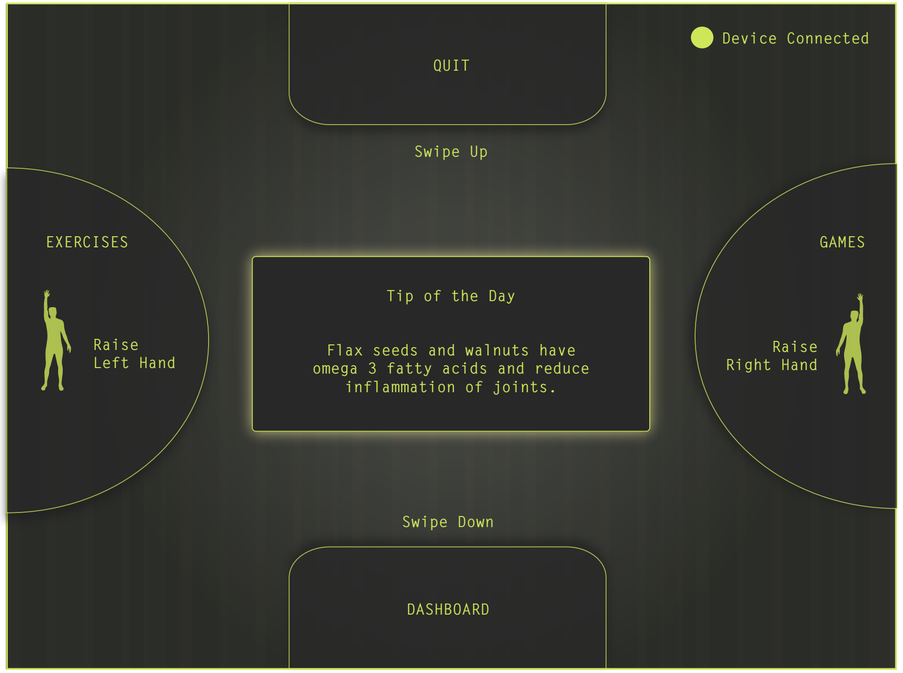
Flax seeds and walnuts have omega 3 fatty acids and reduce inflammation of joints.

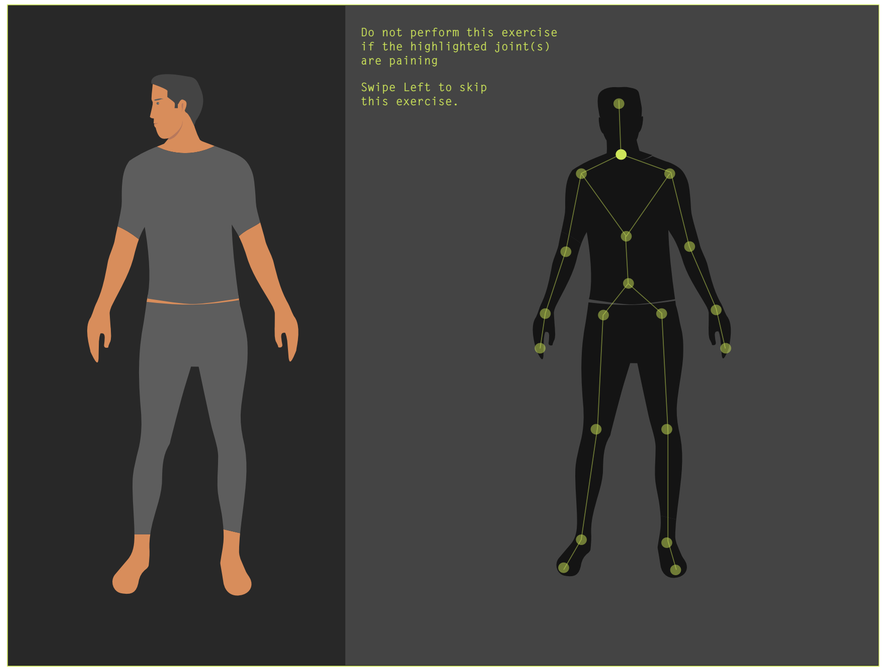
EXERCISE REGIME

FLOW

- Welcome screen
- Exercise, Game options
- Demo screen
- Tracking and feedback
- Exercise feedback
- Session feedback







EXERCISE REGIME

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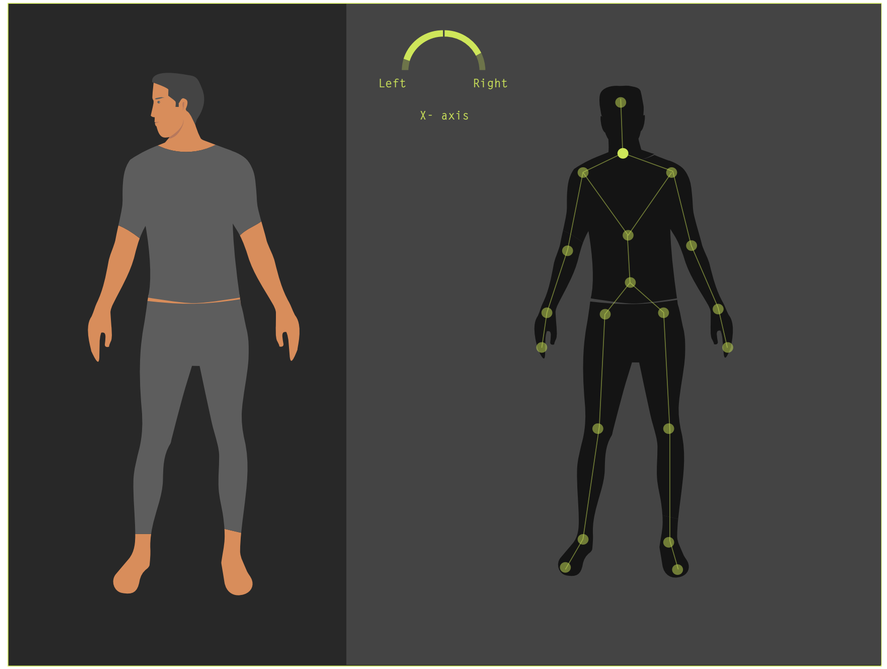
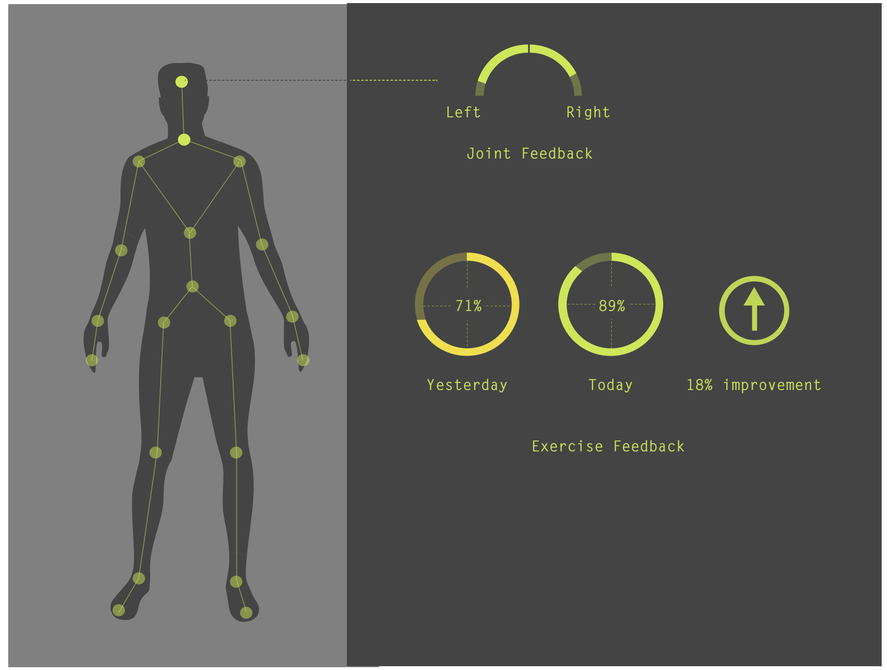
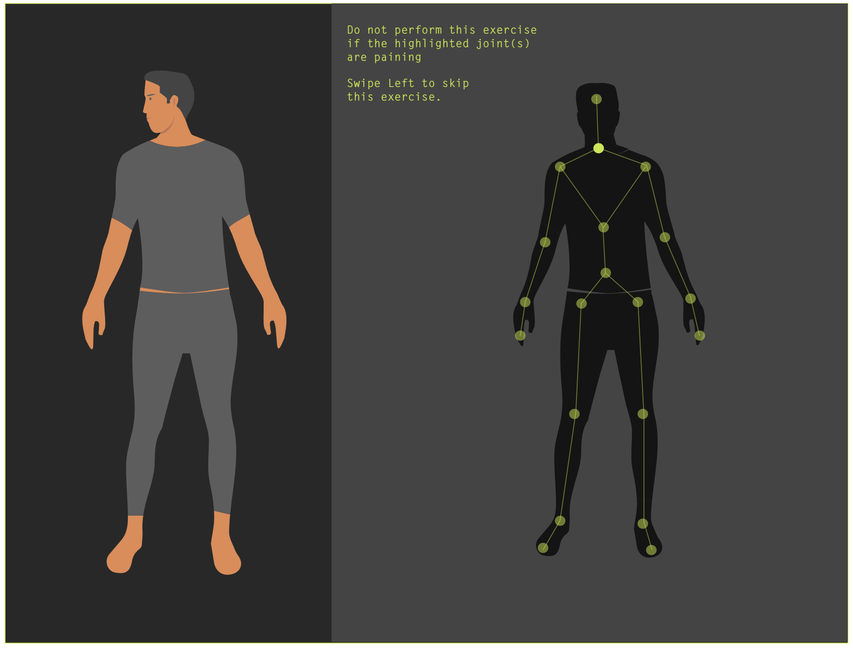


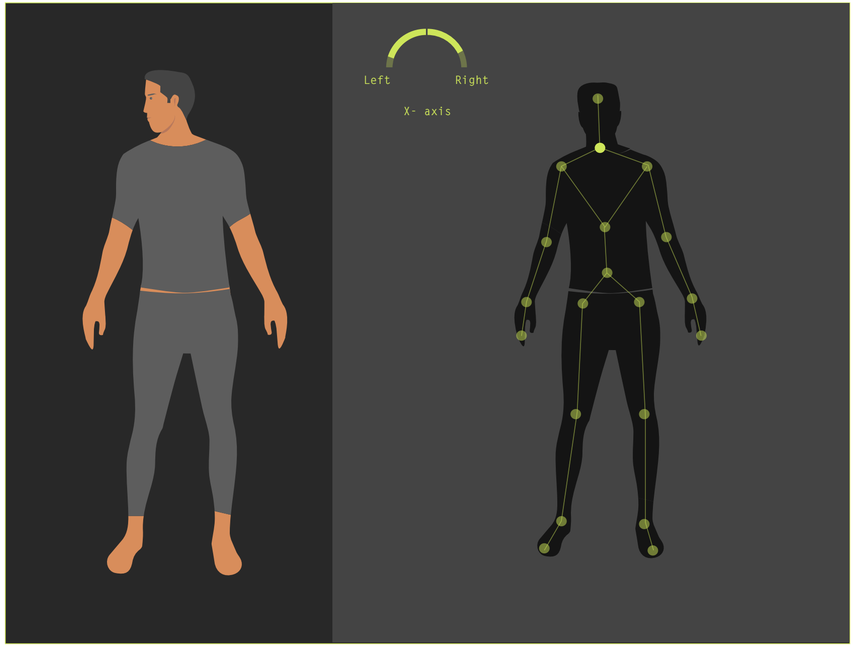


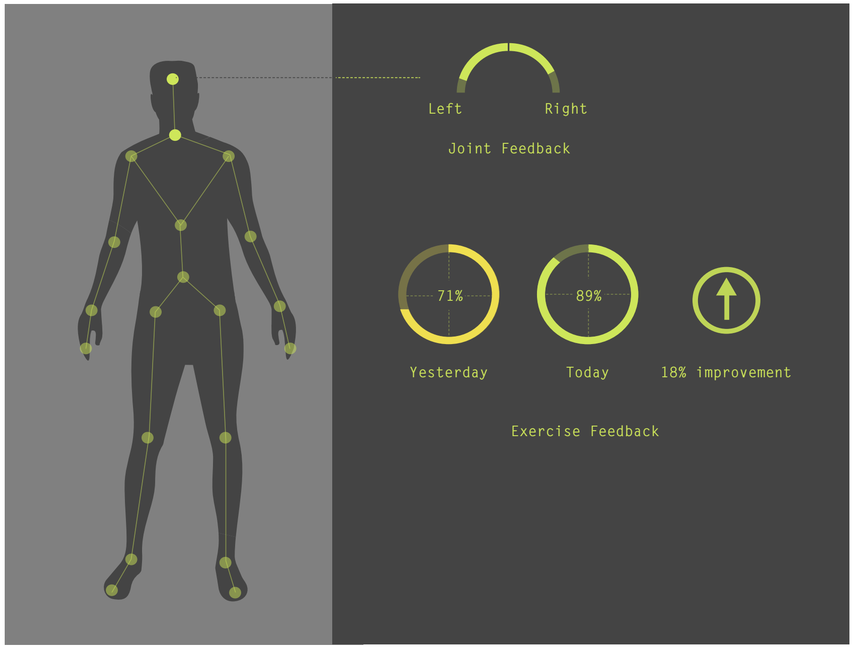
PATIENT FEEDBACK AND INSIGHTS

EXERCISE REGIME - TRACKING AND FEEDBACK

- Patients not in a mental and physical state during exacerbation
- Conditions are expressed in different colloquial terms
- Therapists control speed to avoid jerks
- Yesterday - Today comparison difficult to understand
- Skip option removed
- Feedback through visuals, avoiding textual information
- Speed guide for patients while they are tracked
- Feedback day explicitly mentioned

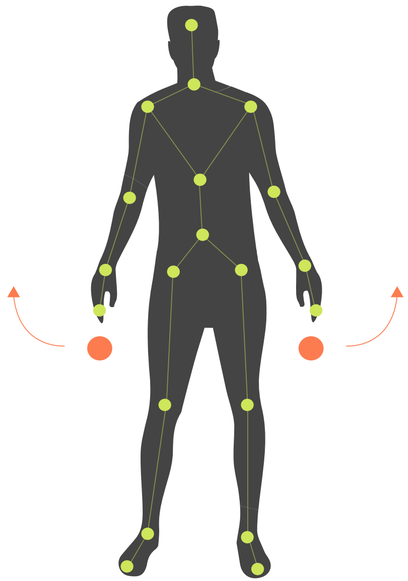


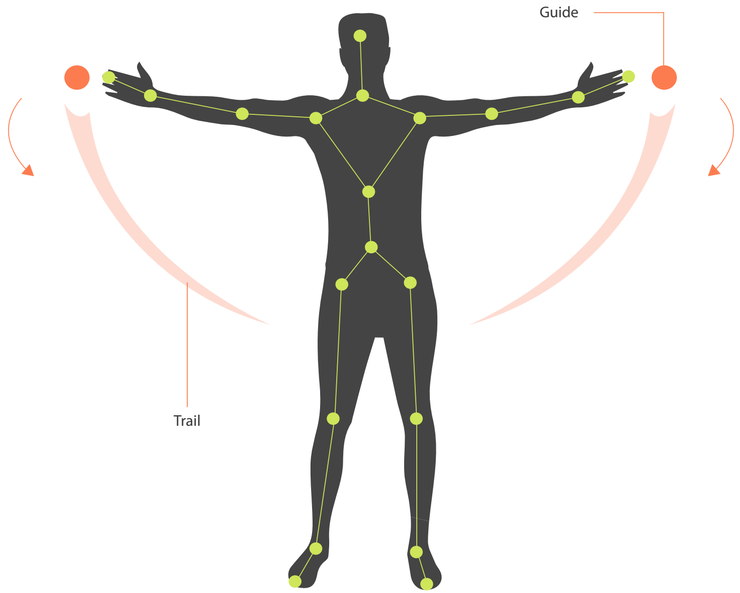


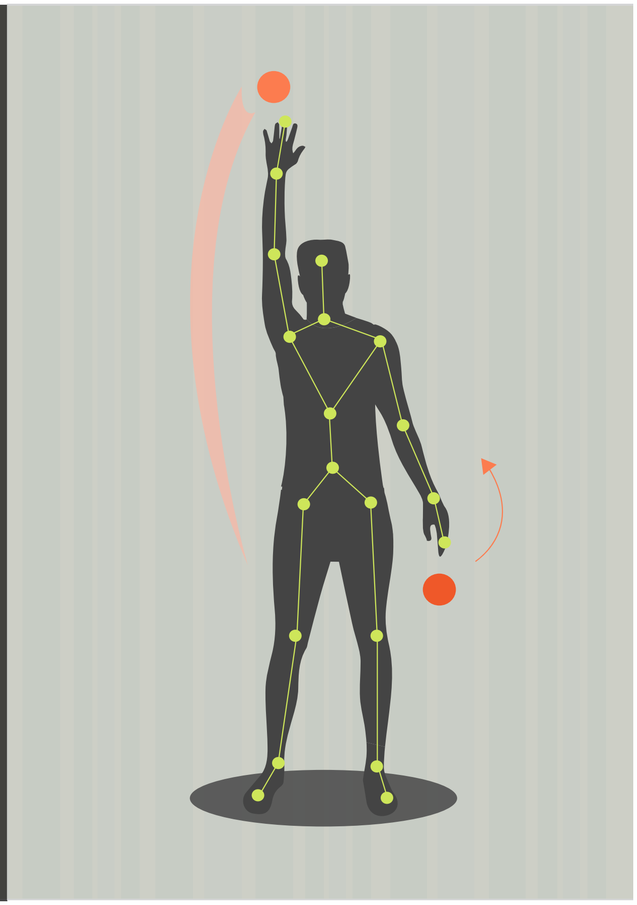


EXERCISE REGIME VISUAL GUIDE

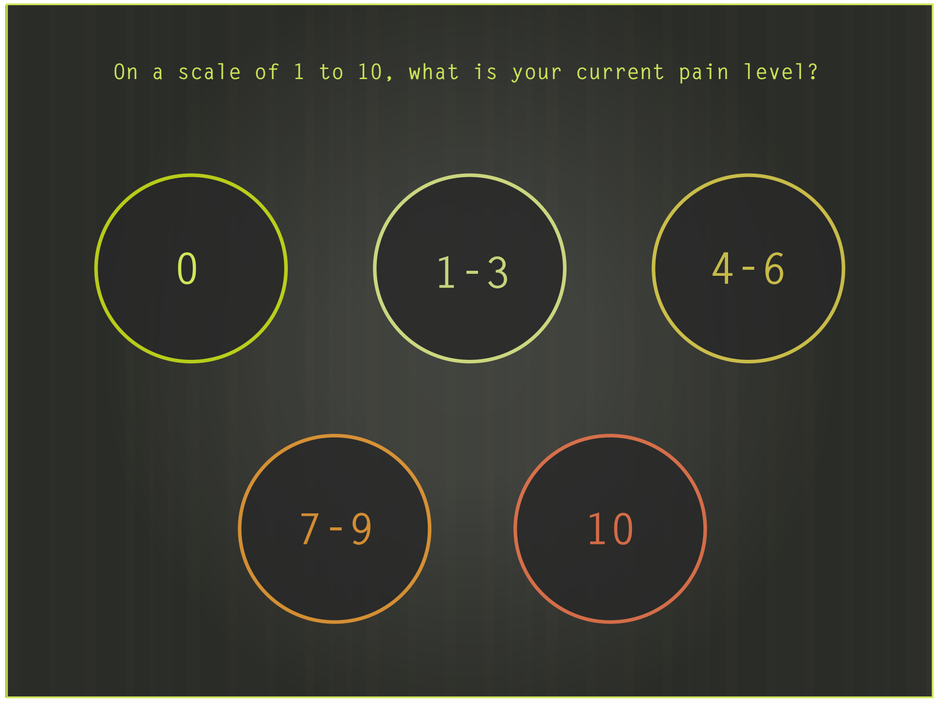
- Audio and visual guide to control speed
- Avoid jerks and spasm
- Audio in form of a pattern for patients to remember







THERAPIST FEEDBACK

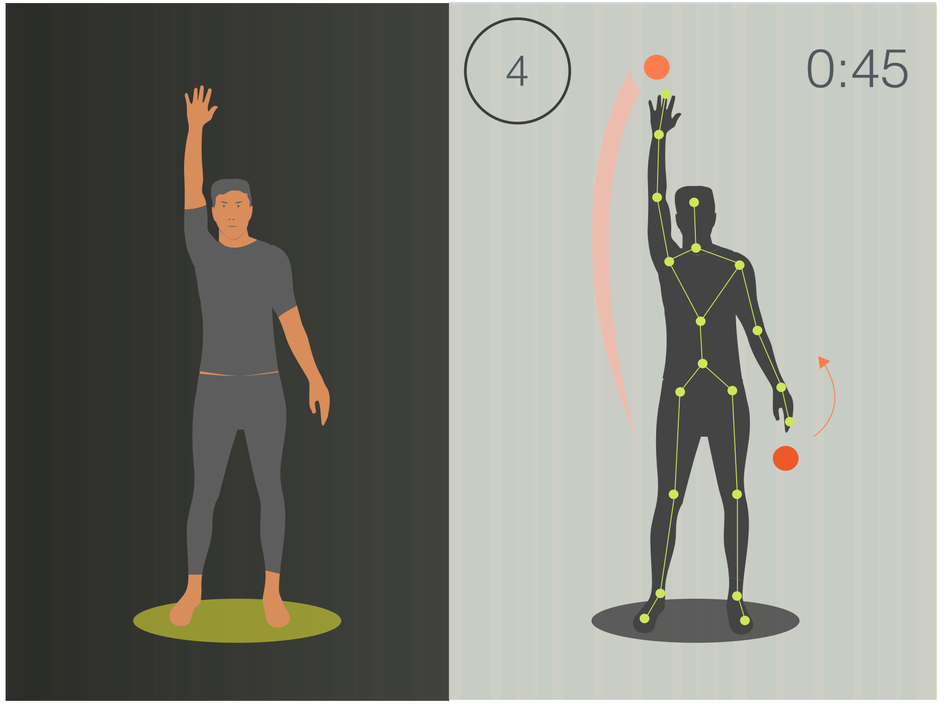


Considering parameters therapists would evaluate progress on

- Asking patients their pain level before and after the session (after login screen)
- Giving session / exercise duration
- Number of repetitions done for an exercise
- Visually representing exercise and session feedback

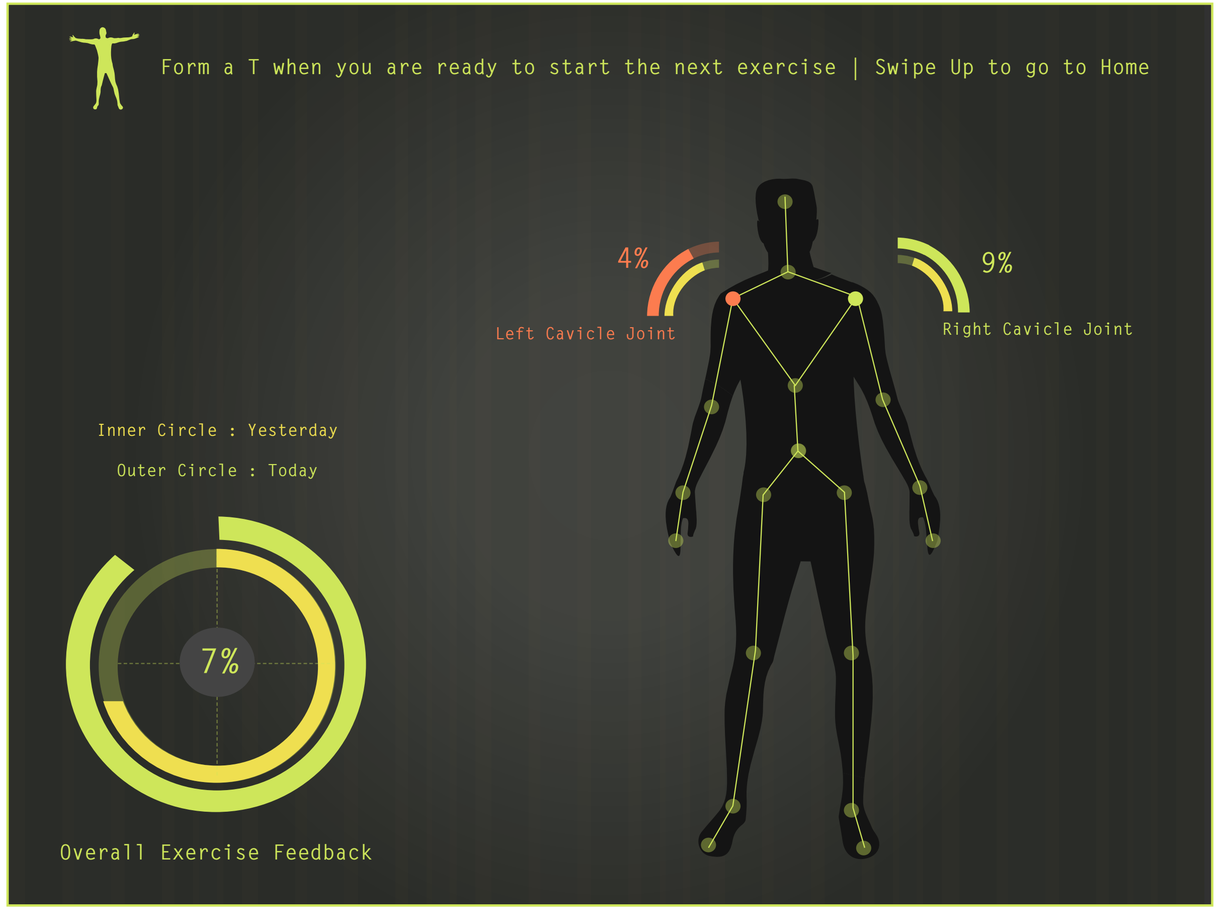
Other incorporated features :

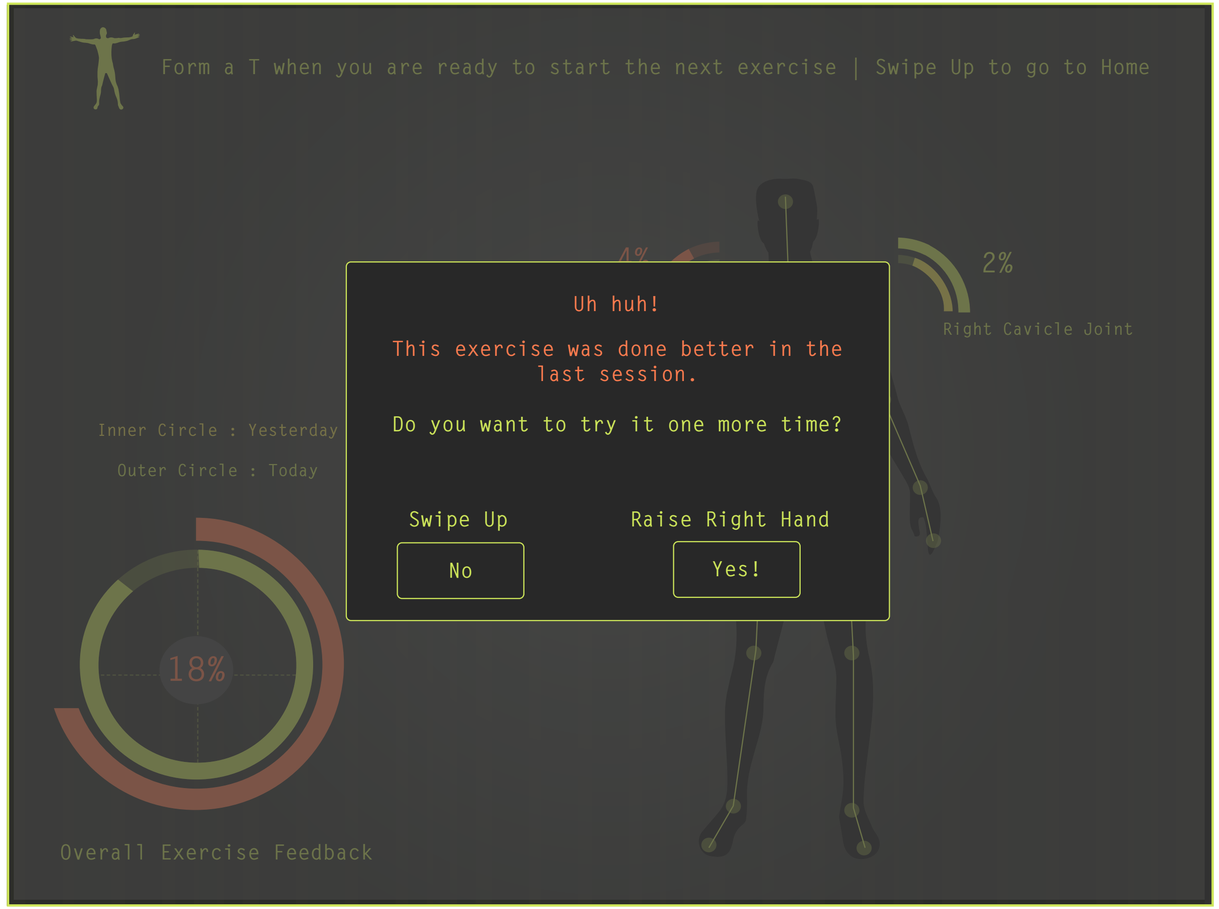
- Gesture based tracking
- Perfectly done exercise immediate audio feedback



EXERCISE REGIME EXERCISE FEEDBACK

Detailed out exercise feedback after therapist and patient consultation Gestures to proceed, Redo option in case of deterioration

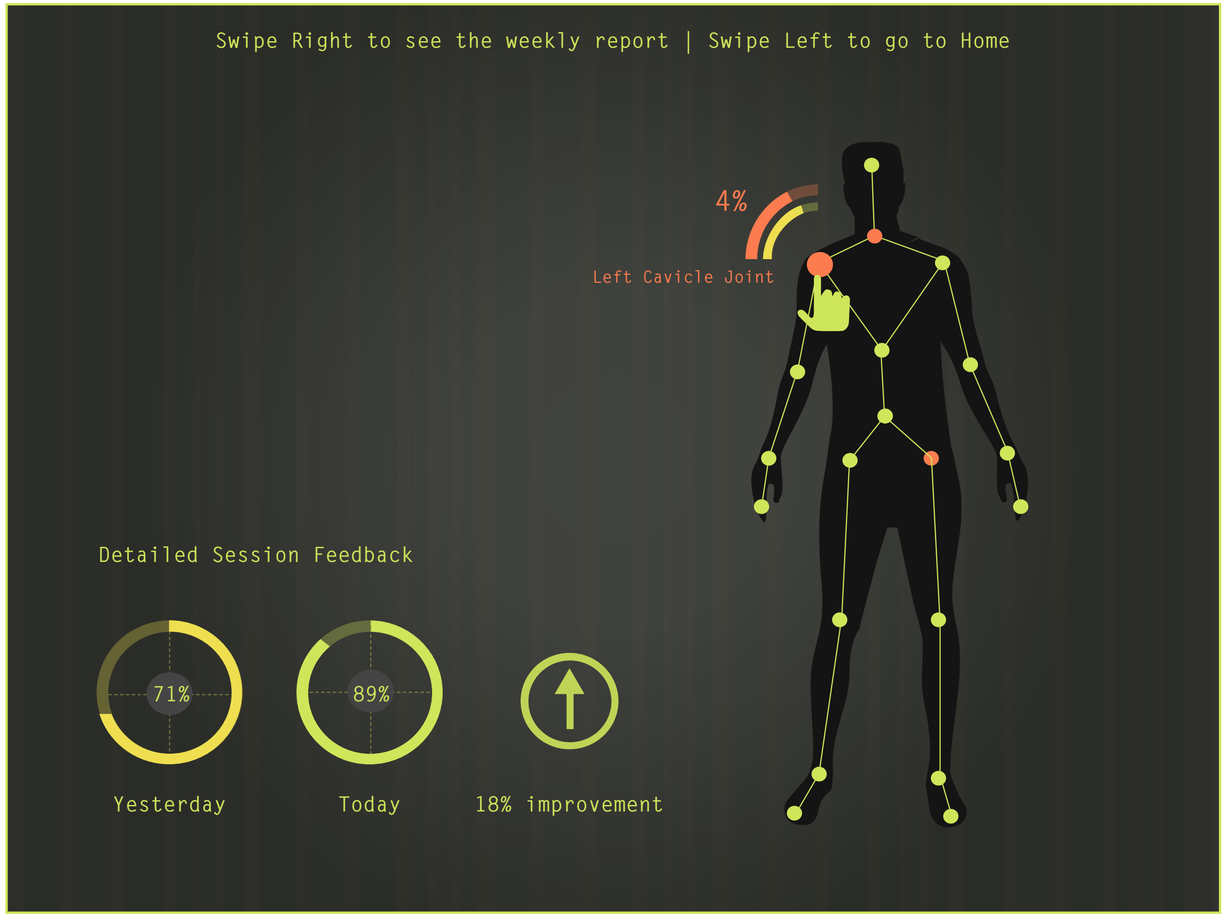


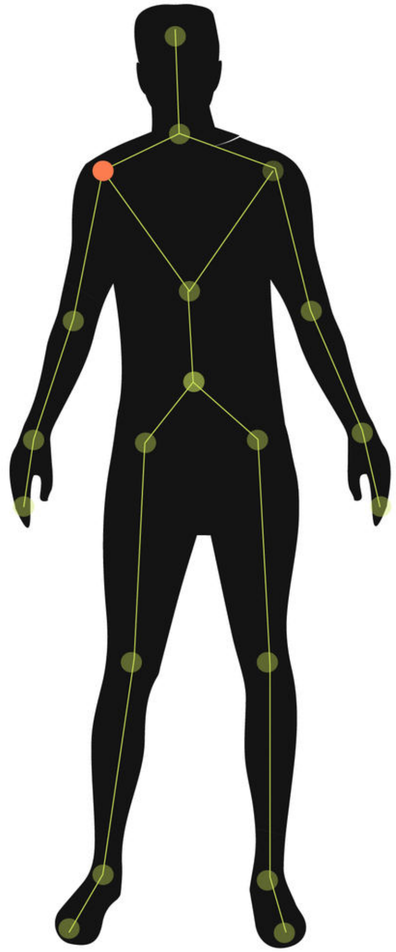


EXERCISE REGIME SESSION FEEDBACK

Session feedback, joint information on hover

Drawback - different planes with different range of motion





PILOT FEEDBACK

EXERCISE REGIME - ENTIRE FLOW

PATIENTS

- Hand cursor should be kept in all the screens
- Text difficult to understand
- Screen should be larger
- Audio feedback mistaken as exercise feedback
- Overall session feedback is sufficient
- Some gestures performed differently by different patients (e.g :- Wave)
- Patients following animation demo even while getting tracked

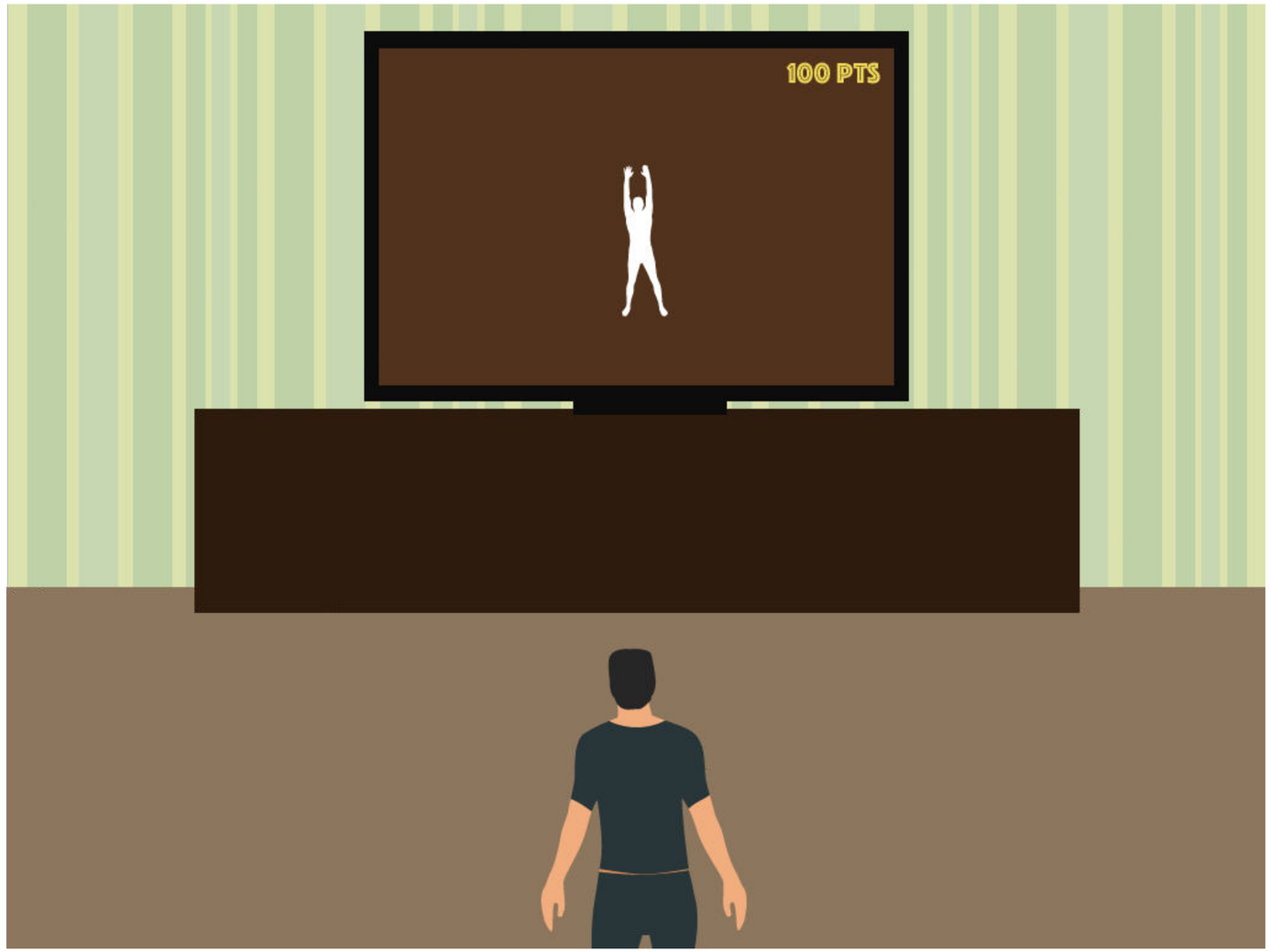
THERAPIST

- The instructions were too small to be read from a distance
- Click a difficult gesture to input pain level
- Audio feedback in form of defined metronome beats
- Current audio and visual guide was considered slow.
- Suggested beats per minute were 30-50.

GAMES

SHAPE UP - FEATURES

- Matching silhouette on screen
- Posture demonstration through silhouette
- Gradual increase in speed
- Auto Repeat if not done correctly
- Mini rounds for practice
- Hints to achieve the shape (difficult)
- Posture Feedback through colour code



PATIENT FEEDBACK

GAME

- Testing with postures drawn on cardboards
- Patient was engaged, followed diligently
- Extrinsic motivation factors were not considered important
- Postures were remembered
- Multiplayer option was suggested
- Increasing speed might result in jerks

GAMES

- Immediate success and failure feedback
- Score reduction if posture not correct
- Difficulty levels set - standing followed by crawling
- Gradual increase in speed component removed
- Shapes abstracted to minimise matching errors

PILOT FEEDBACK

GAME

THERAPIST FEEDBACK

- Perception of shape should not be the challenge
- Achieving the posture the ideal challenge
- Embedding real life activities
- Sequence rather than static postures

PATIENT FEEDBACK

- Range of motion feedback needed after game
- Faster, hence preferred provided session feedback available
- Knees hurting while in crawling position

FINAL CONCEPT

- Prerequisites added
- Detailed instructions
- Visual of gestures
- Large fonts and icons

Hello!

MAKE SURE YOU HAVE THESE



CHAIR MAT TOWEL

SWIPE UP TO QUIT

RAISE RIGHT HAND

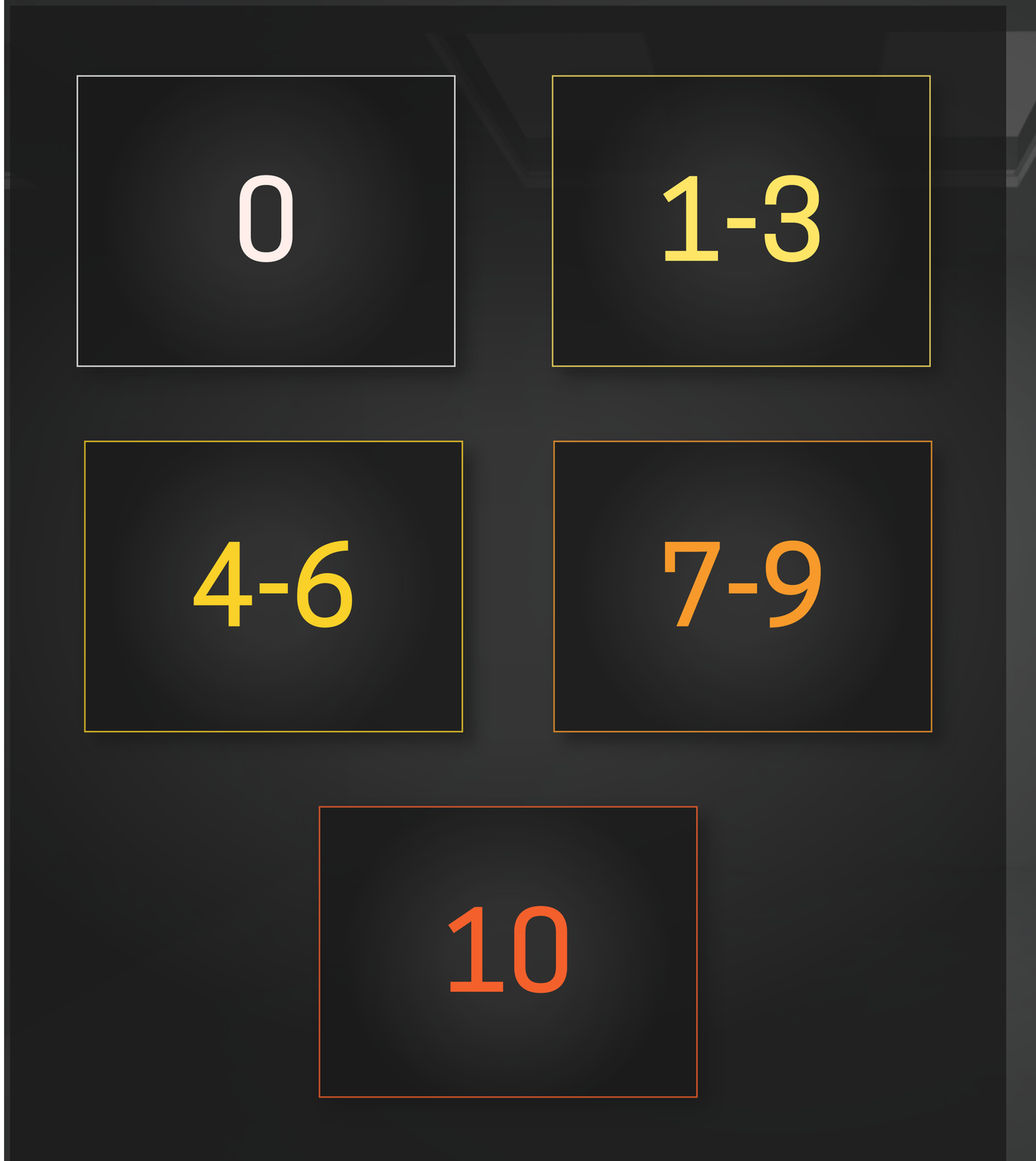
TO PROCEED

FINAL CONCEPT

- Embedding disease knowledge on screen load

FINAL CONCEPT

- Circles to rectangles for larger area
- Click to select and hover cursor



FINAL CONCEPT

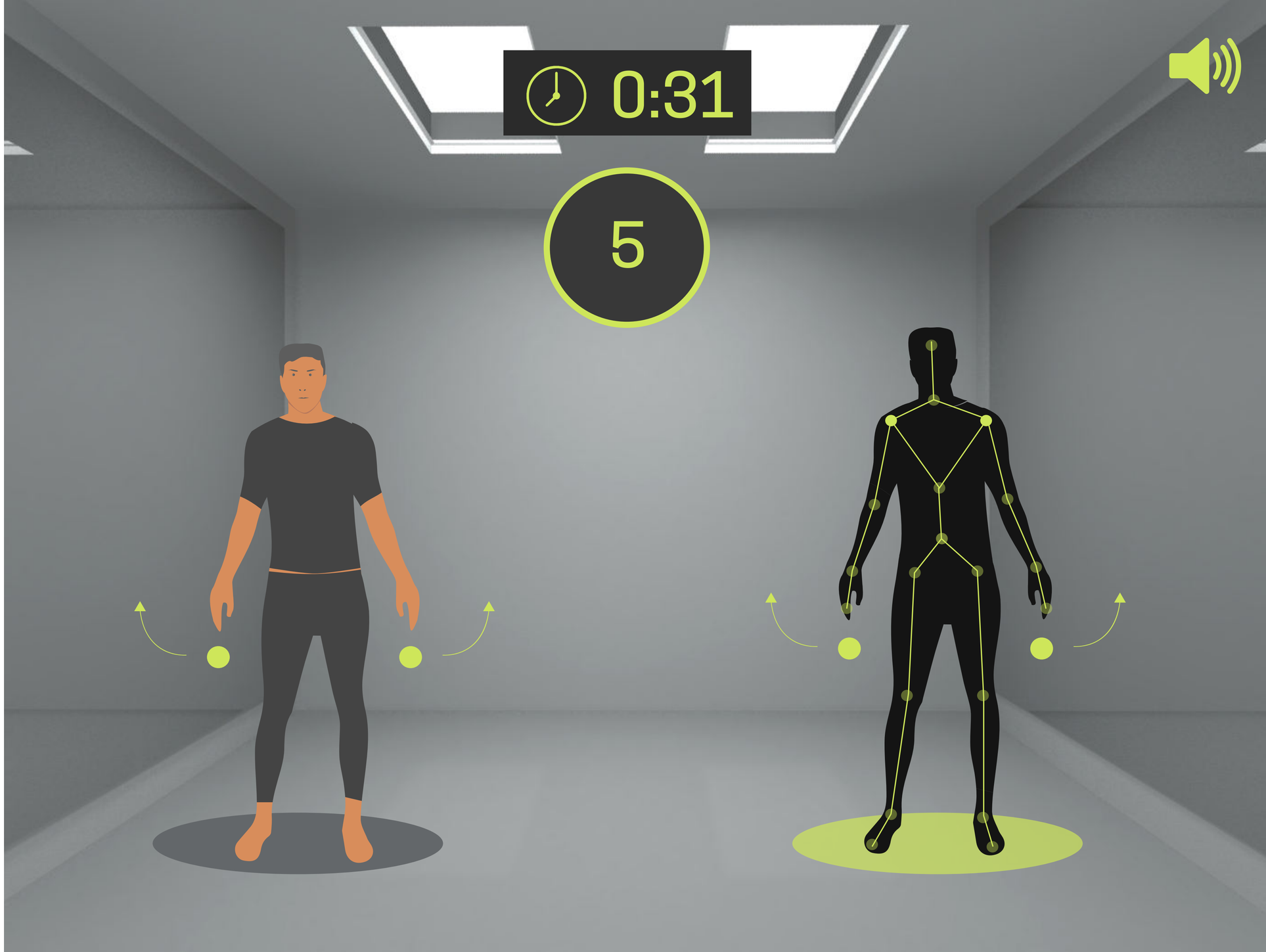
- Real estate used completely
- Technical terms like ‘Dashboard’ replaced with simpler terms

FINAL CONCEPT

- Visual guide added for instructor
- Depth added in the back drop for future exercise additions

FINAL CONCEPT

- Session time
- Repetitions done
- 40 bpm audio guide
- Highlighted joints
- No skip option in between repetitions
- Avatar replaced with real time feed to eliminate lag
- Position fixed for patients for optimised tracking
- Idle time calculator



FINAL CONCEPT

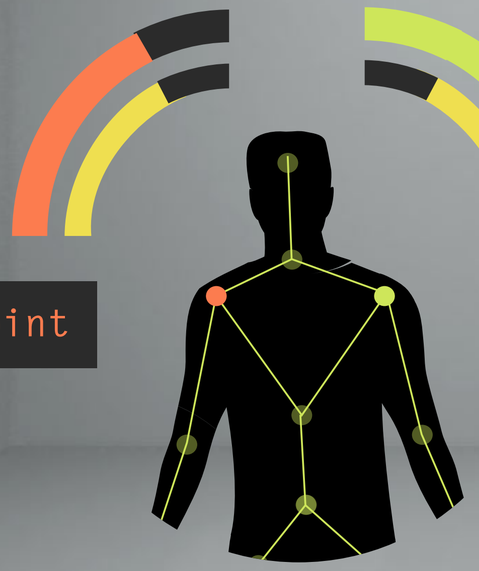
- Animated session feedback
- Showing region of interest only in exercise feedback

OVERALL IMPROVEMENT

7%

2%

9%



Left Cavicle Joint

Right Cavicle Joint

Outer Arc: Today

Inner Arc: Yesterday

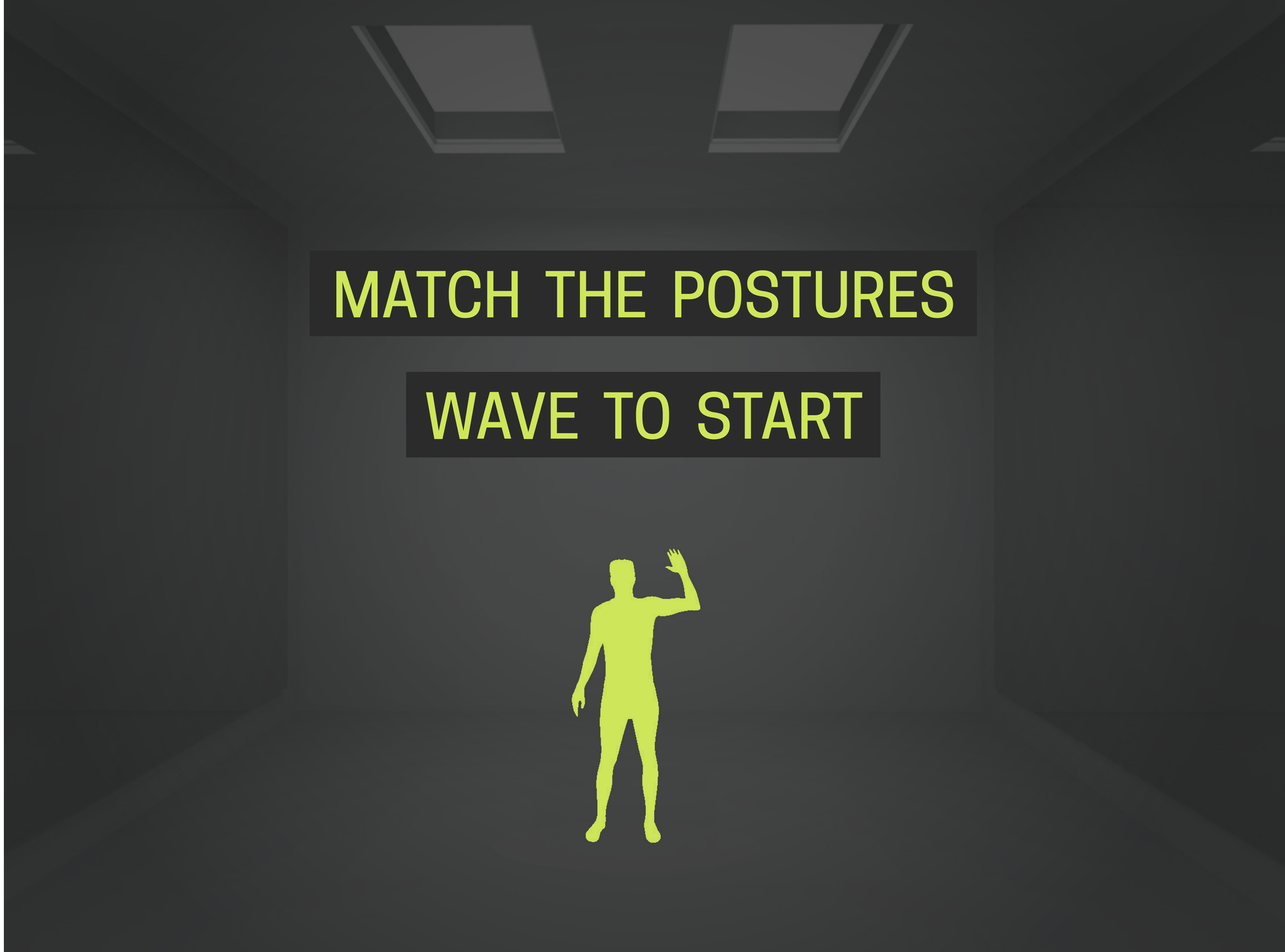
HOME

SWIPE UP

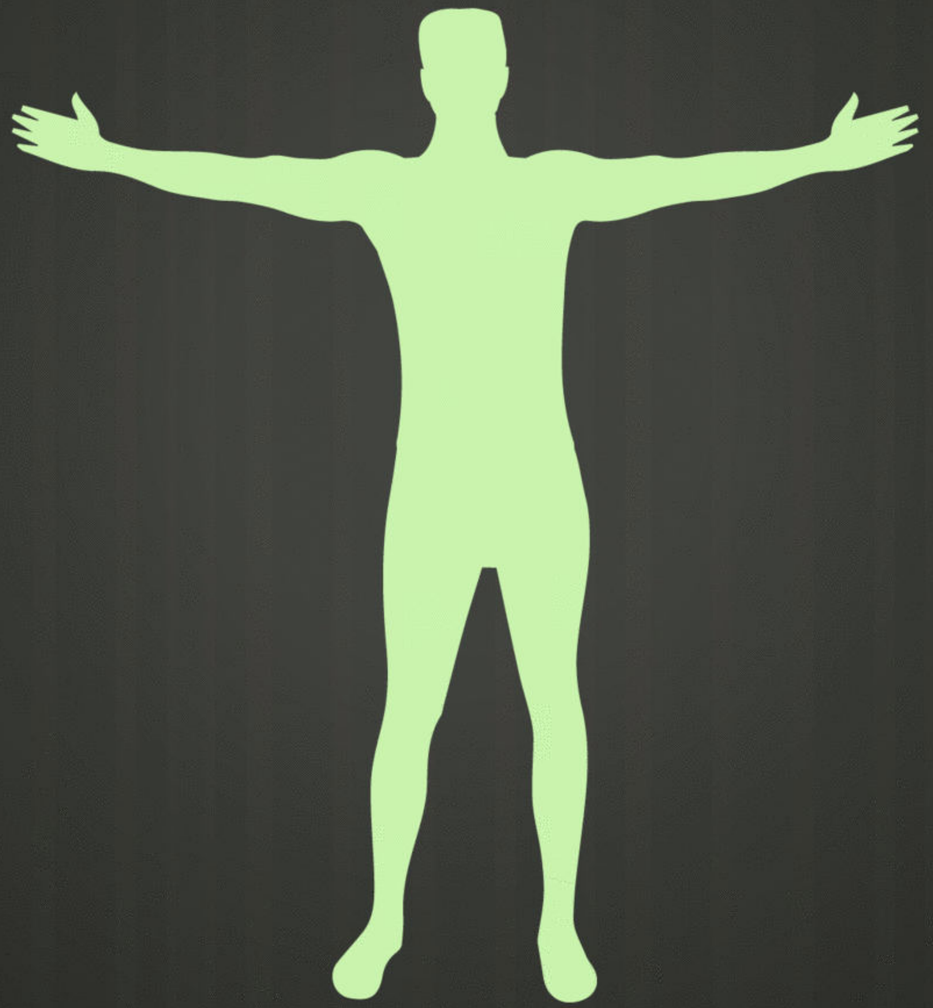
NEXT »

FINAL CONCEPT

- Animated visual of gestures
- Reducing perception ambiguities
- Removing abstraction from the silhouettes



FINAL CONCEPT



WALK OUT TO QUIT

PROTOTYPE

EVALUATION PLAN

EXERCISE REGIME

A. Gesture : For UI control
   - Intuitiveness
   - Reliability
   - Ability

B. Exercise : Feedback and Tracking
   - Mapping audio vs movement speed
   - Mapping visual guide vs movement speed
   - Feedback visualisation
   - Tracking accuracy

C. System Adaptability

1. Did you feel any pain while navigating through the system? If yes, what was the VAS level? A
2. Did you find it difficult to follow the instructions while operating the system? C
3. Which type of instruction could you focus on, audio or visual? B
4. What could you interpret from the feedback you received after exercising? B
5. How good are you with operating desktops and laptops? C
6. Would you be comfortable operating this system alone next time? C

EVALUATION PLAN

GAME

A. Patient engagement
B. Extracting exercises from games.

1. How long you think you played the game? A
2. Did you face any confusions faced while playing the game? A
3. Were you eager to know what silhouette would be given in the next turn? A
4. Did you look at the kinect while playing the game? A
5. What was the instructor doing while you were playing? A
6. Could you identify any exercise while playing the game? B
7. Can you replicate a sequence that was shown in the game? B

EVALUATION

EXERCISE REGIME - PATIENTS

A. Gesture : For UI control

- Click gesture performed with ease to input pain level
- No difficulties in understanding the gestures
- No pain (VAS = 0) while performing the gestures
- Problem with Tpose gesture detection, average number of tries 3

B. Exercise : Feedback and Tracking

- Visual guide more intuitive, metronome might be ‘irritating’ after sometime
- Feedback was understood (neck abduction / shoulder stretching)
- Different beats with matching tempos could retain interest of patients
- Would not quit because of boredom, would quit if tired.
- Feedback should be ‘Last Time’ vs ‘Today’
- All repetitions tracked properly, average exercise time 30-40 seconds

C. System Adaptability

- Patients did not find the connection difficult
- Would not have a problem to control the system alone

EVALUATION

EXERCISE REGIME - PATIENTS

- Patients think they are not been able to replicate the gesture.
- All patients will not be interested to view feedback for all joints.
- Patients interested in seeing feedback of affected joints only.
- Concern with the accuracy of the system initially.
- Improvement in range of motion (ROM) strong motivator.
- Patients interested to know the current ROM and improvements if any.
- Mostly comfortable in doing exercises alone.

EVALUATION

GAME - PATIENTS

- Patients thought they played for 2-3 minutes or less.
- Current postures include only cardio
- Patients were oblivious about the what the instructor was doing
- Did not think about what posture would come next
- Did not look at the tracking device
- One patient could replicate chest rigidity sequence
- All patients could mention at least one sequence of postures
- Patients trying to match postures exactly
- Tpose recognition difficult, patients tried matching leg orientations
- A report at the end of the session main motivator, should be included in games as well

EVALUATION

EXERCISE REGIME OR GAMES

- Intrinsic motivation overpowers extrinsic motivation offered by games
- Would not switch to games if suggested by the system
- Game preferred only because it is faster and option to quit any time
- Would prefer accuracy over shorter duration, ROM feedback ultimate requirement

FUTURE WORK

- Integrating all the suggested exercises.
- Integrating remote supervision feature.
- Adding difficulty levels in the game.
- Including dynamic postures in the game.
- Optimising tracking algorithm.
- Increasing reliability, accuracy of the system.

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