CSE 176A/276D Project Final Report

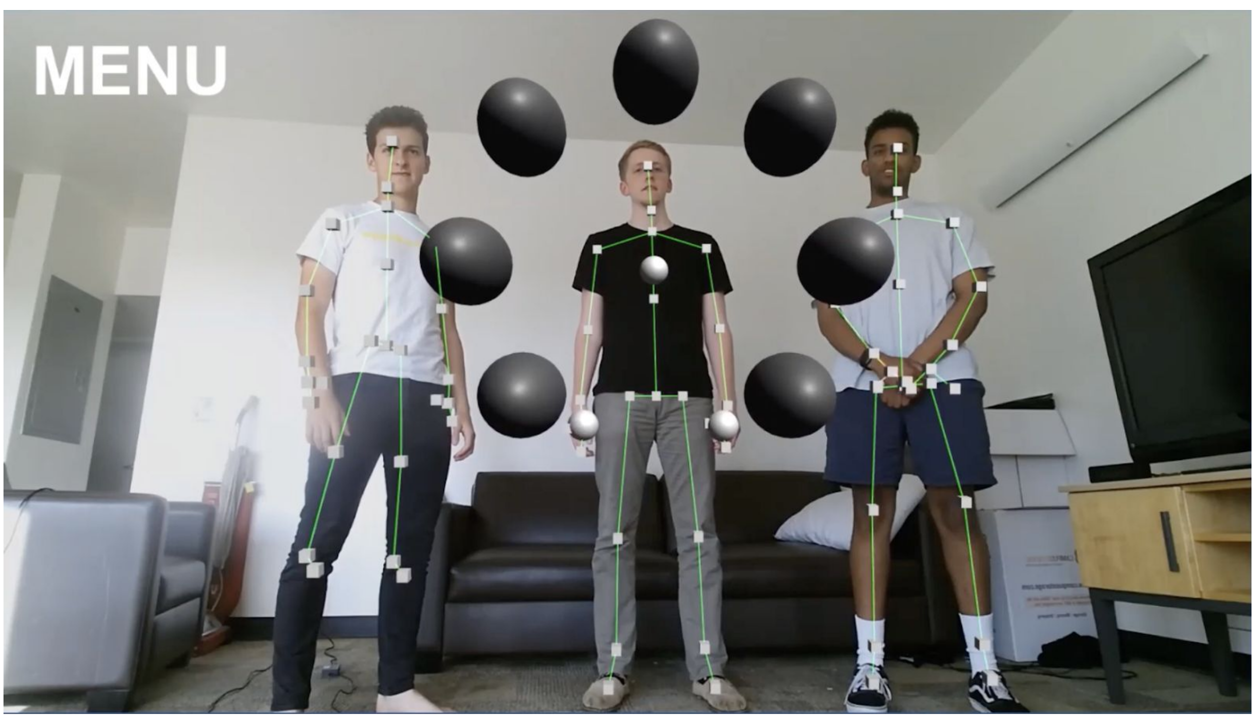
KCP: Kinect for Cognitive and Physical performance

A cognitive assessment tool promoting exercise for individuals at risk of dementia.

Luke Rohrer Role: Project setup, body tracking, Unity and Kinect SDK integration, collision detection, game interface/.

Victor Bourgin Role: Reaction time game implementation, research and inspiration, video edition and incorporation

Nathan Werrede Role: Simon Says implementation



From left to right: Victor, Luke and Nathan

1. Executive Summary

The population of those with dementia has grown substantially, with an affected population projected to 25% in Europe and North America by 2030 [1]. While regular cognitive assessments are necessary for early diagnosis of cognitive decline, exercise and physical therapy routines have been shown to mitigate cognitive decline and memory loss, the two most common symptoms for dementia. Kinect for Cognitive Performance, or KCP, is a system for convenient physical therapy exercises and cognitive assessments.

The KCP system is designed to be used at home. It utilizes the Microsoft Kinect, which is a sensor and camera system that captures body positions and distances. We used the Kinect in conjunction with Unity 3D, a video game development platform, to develop a set of cognitive training exercises. We implemented both a reaction time game, made to train and work on reflexes, and an iteration of the game Simon Says, which serves as memory training. We implemented these exercises with using arm and hand motion in mind, as a participant would have to reach and grab to select their choices. We developed a testing protocol for ensuring that our project is working as intended, and analyzed the results of testing to determine the usability of such an idea, against that of app-based iterations of the activities we implemented. Lastly, we cover potential future work with the KCP system, along with some evaluation of the design and implementation of the system.

2. Introduction and Statement of Needs

While people are living longer, more active lives, older adults still have to attend to the prevalence of neurological diseases, namely Alzheimer's disease, one of the predominant causes of dementia. Dementia is a group of symptoms caused by an underlying medical condition that impairs cognitive function, causes behavioral changes, and interferes with normal activities [1]. Dementia, including Alzheimer's disease, progresses slowly, and over a long period of time [1], with cognitive decline being one of the most important consequences. The study of these degenerative neurological diseases is of particular importance as they currently cannot be prevented, cured, or slowed.

We've identified a need for tests that both measure and aim to improve cognition, especially considering that declines in memory and cognition are two of the most common symptoms of people with dementia [1]. Monitoring individuals as they are undergoing cognitive tests is essential to detect and work with cognitive decline, and early detection is crucial for the symptoms to be treated effectively.

As it stands, cognitive tests require the participant to visit a clinic, to undergo clinical tests, which require the presence of a doctor or clinician. There arises the problem of mobility and transportation, as older adults cannot often visit clinics independently for routine testing, for long periods of time. Home monitoring systems such as applications are suited for use at home, but suffer from poor adoption rates among older adults.

Physical exercise is of paramount importance for general health, and for cognitive health as well. Routine physical exercise is helpful in preventing the onset of Alzheimer's disease. Adults who who routinely engaged in physical activities, sports, or regular exercise in midlife carried a significantly lower risk of dementia years later [2]. Physical exercise is also great for limiting cognitive decline. There are currently obstacles for older adults to attain frequent exercise, and physical therapy. Access to exercise trainers can be limited depending on location, and seeking out exercises to do can be complicated and overwhelming.

We have thus identified the need for home-based physical exercises, to add the convenience factor to cognitive and physical training, so that it can be more widely available to individuals that would otherwise not have access to such resources. We are able to extend this functionality to those who are in need of physical therapy, such as individuals who have suffered a stroke.

Our project is aimed to be an automated personal trainer, that encourages individuals, particularly older adults, to exercise regularly and monitor their cognitive health. The key stakeholders for our project are older adults, namely those who may be impacted by neurological diseases, but also other adults that desire to monitor and train their cognitive and physical health. We aimed at developing gamified exercises to increase adherence, and ensure regular use, as they would be more interactive than clinical tests. These games would be designed to assess and improve cognitive capabilities, which will help prospective users exercise more often and monitor their performance. We aimed at developing tests designed to assess memory and psychomotor speed, or reaction time.

We have implemented two games that serve as tests to cognitive and motor function. The first game, a reaction time test, is based on a Cambridge Neuropsychological Test Automated Battery (CANTAB) test for psychomotor speed, which has demonstrated sensitivity to detecting changes in neuropsychological performance [3]. The next game we implemented is a form of Simon Says, in which there is a growing sequence of colors and sounds a participant has to answer correctly, where they have to remember the sequence, including the newest color and sound. Serial recall is important for measuring memory function, and is subsequently useful for identifying dementia in older adults [4].

We utilized the Microsoft Kinect and Unity 3D for the implementation of our project. The Kinect software development kit (SDK) contains functions that identify user movements and manage user interactions, and when used in conjunction with Unity, a game development engine, we were able to make these exercises more interactive, and by gamifying them, user adoption would likely be enhanced.

3. Methodology

3.1. Project design process

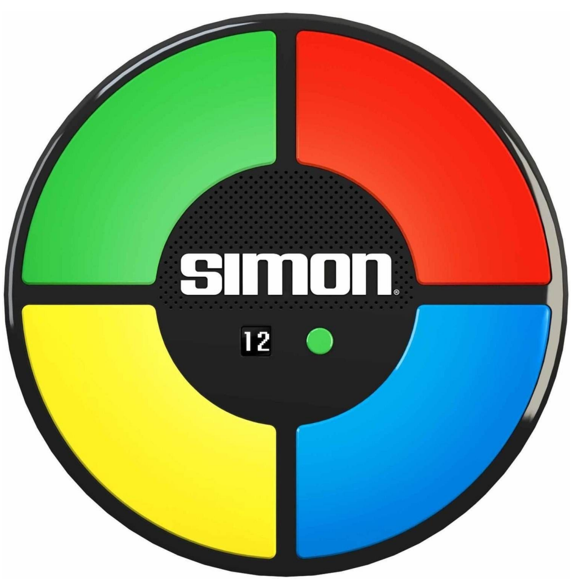
In section 2, we examined key stakeholder needs to help guide the design of our robot. Specifically, we identified the importance of regular cognitive testing for detecting the onset of dementia, and the limitations of current cognitive assessment tools in ensuring adherence among older adults. Furthermore, the importance of physical exercise for the prevention and treatment of symptoms of dementia was recognized.
We thus aimed at developing fun, home-based exercises that could be performed by an individual for their cognitive capabilities to be evaluated. Our robot would be used to encourage individuals to perform these exercises regularly such as to prevent, detect and treat common causes of dementia such as Alzheimer’s disease, with potential applications in other healthcare sectors such as physical rehabilitation for individuals recovering from a stroke.

Our main objective was to design physical activities that could be used to measure an individual’s cognitive abilities based on how well they do in the tests. For this, a literature research allowed us to identify commonly-used cognitive assessment tools. The Reaction-Time (RTI) test developed by the University of Cambridge as part of the CANTAB is a highly cited tool for measuring psychomotor speed, while the Simon Says game can be used as a fun assessment of short-term memory, a crucial indicator of cognitive decline.

In the CANTAB RTI application, five circular zones are displayed on a screen. The user initially keeps his finger pressed in a ‘home’ position. After a given time, one of the circles randomly changes color, and the time for the user to press the correct circle is measured to evaluate the individual’s reaction time (figure 1).

Figure 1: The CANTAB RTI test.
https://www.cambridgecognition.com/cantab/cognitive-tests/attention/reaction-time-rti/

Simon Says, on the other hand, is a widely known game that requires the user to memorize an ever-growing sequence of colors coupled with sounds, and repeat the sequence. It often takes the form of a toy or an app (figure 2).



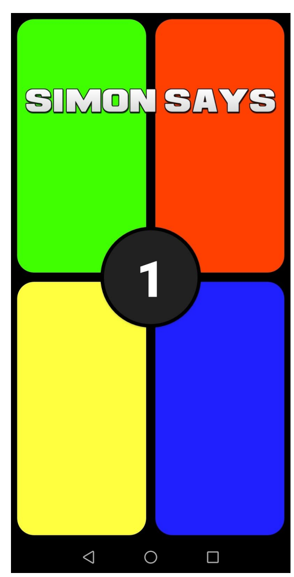


Figure 2: Simon toy (left) and app (right)

We thus desired to develop physical equivalent of RTI and Simon Says. For this, we first established four main functional criteria for our robot to be used for physical exercise:

1. Prompt the user to perform adequate movements
2. Detect user movements
3. Evaluate user performance
4. Provide feedback to the user

An initial storyboard illustrating our robot's ideal functionalities is shown in figure 3.

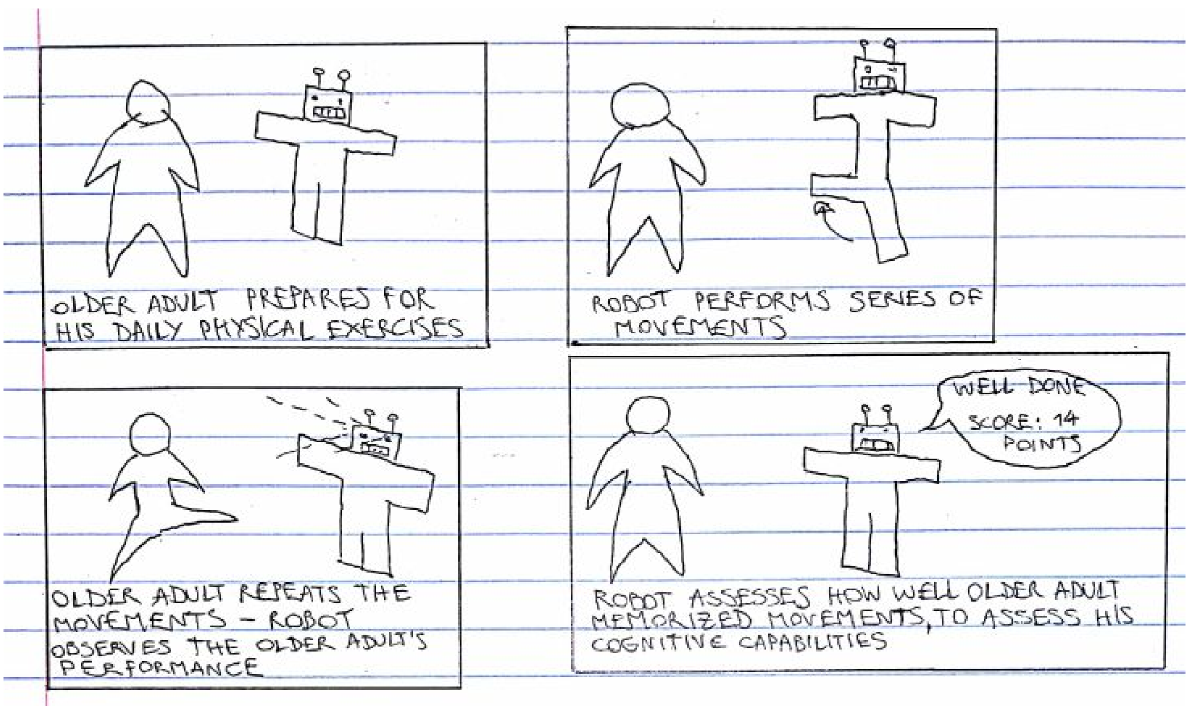


Figure 3: Initial storyboard for KCP

From the material that was made available to us as part of the project, we thought about using either the Turtlebot or the Kinect for their movement-detection capabilities. The turtlebot would allow for additional feedback and user interaction through physical motion, but the Kinect was chosen as a good starting point. Indeed, it is equipped with an RGB-D camera that can track user movement and determine the location of up to 20 joints. A Kinect SDK is also available for developing applications supporting gesture tracking and control.

To increase user adherence, we wanted to gamify our cognitive assessments. For this purpose, we decided to use Unity, a game design platform that has been used to create more than 50% of the games available worldwide. It was chosen for its extensive functionalities, ease of use, and for the Kinect Unity package that can be downloaded from the Microsoft software store. This will allow us to combine the motion-sensing capabilities of the Kinect with a gamified graphical interface made on Unity.

We thus came up with a more detailed storyboard (figure 4), coupling the Kinect's tracking capabilities with games developed on a PC using Unity.

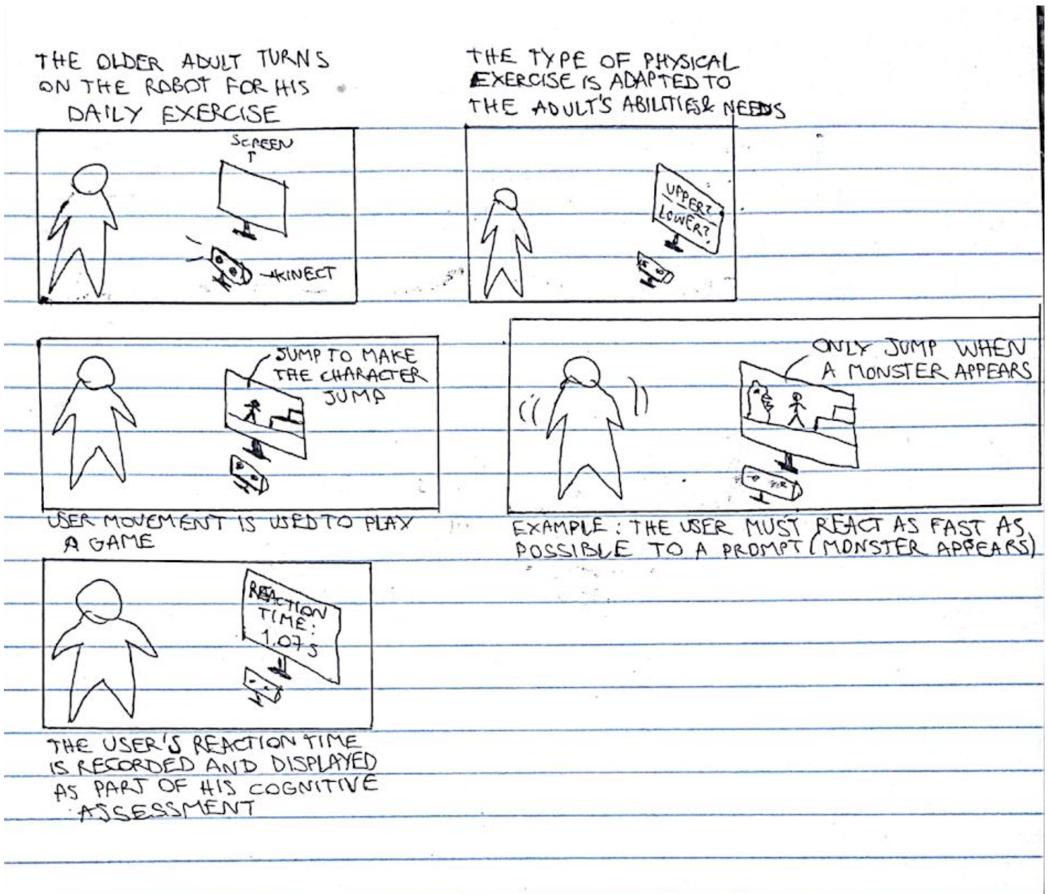


Figure 4: Storyboard coupling movement tracking and a game.

We ideated some methods for creating exercise-based equivalents of the RTI and Simon Says tests to be implemented with the tools that we had defined, and some general interactions between the user and the robot. We decided to create a user interface similar to the CANTAB RTI and Simon game, as they provide a simple and intuitive way of measuring cognitive abilities.

For this, we conceptualized an interface that would display the live video of the user in their environment, acquired with the Kinect and shown on a computer screen. Zones would be shown on the UI, and the user would be asked to stay in a 'default' configuration. One zone would then randomly be drawn to glow and play a sound, and the user would need to perform a pre-defined exercise to trigger a zone selection. The reaction time would be measured from the glowing of the zone to the user selection.

For the Simon game, we initially wanted a sequence of movements to be shown to the user through avatar animation on Unity, which the user would have to repeat accurately. After further discussion, we decided that the same ‘zone’-based interface as that used for the RTI test could be used to create a minimalist, simple to use integrative platform. Different zones would light up in sequence, and the user would need to perform pre-defined movements corresponding to the sequence shown on the screen. The user’s short-term memory would thus be assessed from their ability to accurately remember and reproduce the sequence.

To refine the tests and gain a deeper understanding of what was feasible, we familiarized ourselves with the Kinect by doing the online tutorials, and tested the interfacing between the Kinect and Unity. We established that the user’s skeleton could be identified at a high level of accuracy for their movements, location and position to easily be characterized. The Kinect could even be used to detect whether the user’s hands were open or closed.

We thus identified reaching and grasping as an ideal interaction and selection tool. The user will just have to reach the zones with their arms and close hand to select them in the different tests. This would allow us to use a similar “point-and-click” method as the application-based cognitive tests. The zones could even be used to create a menu at the start of the session, for them to select a game to play, with each zone corresponding to a different game. The simplicity of the reaching and grasping selection method also ensures that most individuals can perform the cognitive tests, and decouples cognitive ability form physical performance for the former to be solely evaluated.

With the aim of creating a similar user interface as that used in the CANTAB RTI test, we decided to create spherical components around the user for the target zones. The spheres would be within reach of the user, and would move as the user moves in their environment for the robot to remain functional irrespective of the user’s position relative to the Kinect sensor.

Therefore, for the Kinect-based RTI test, a random zones will glow. The user would have to reach the sphere and close their hand inside the sphere to select it. The time between the prompt and sphere selection would be used as a measure of reaction time.

For the Simon game, the zones will glow in a random sequence. The user will have to reach the corresponding zones in sequence, with the selection being performed in the same way as the RTI test, by reaching and closing the hand. If the user reproduces the sequence accurately, the level of difficulty will increase by increasing the length of the sequence. The level reached by the user will be used as a measure of short-term memory.

Our robot was further refined through iterative testing and design. We decided to change the morphology of the zones into ellipsoids, which were found to be more simple to locate in space. User-testing also allowed us to set the ideal distance between the zones such that they could be reached by most individuals. The timer duration between prompts was also set according to user feedback, for the user to have time to rest without having to remain idle for too long. Finally, we recognized the need for an instruction video to be played at the start of each test, for the user to perform the movements properly. A final storyboard is shown in figure 5.

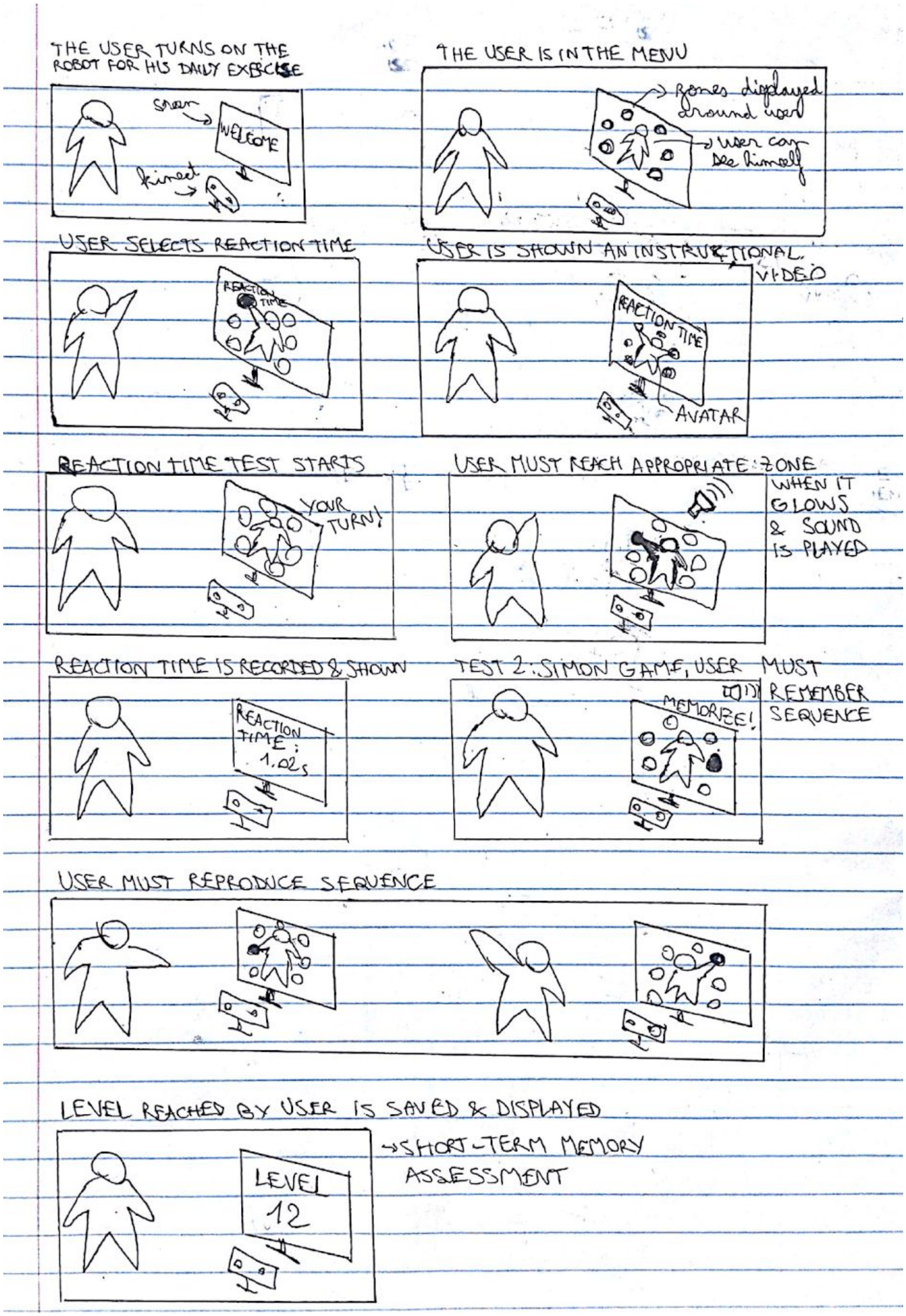


Figure 5: A final storyboard for KCP, showing the RTI and Simon tests

3.2. High-level overview diagrams

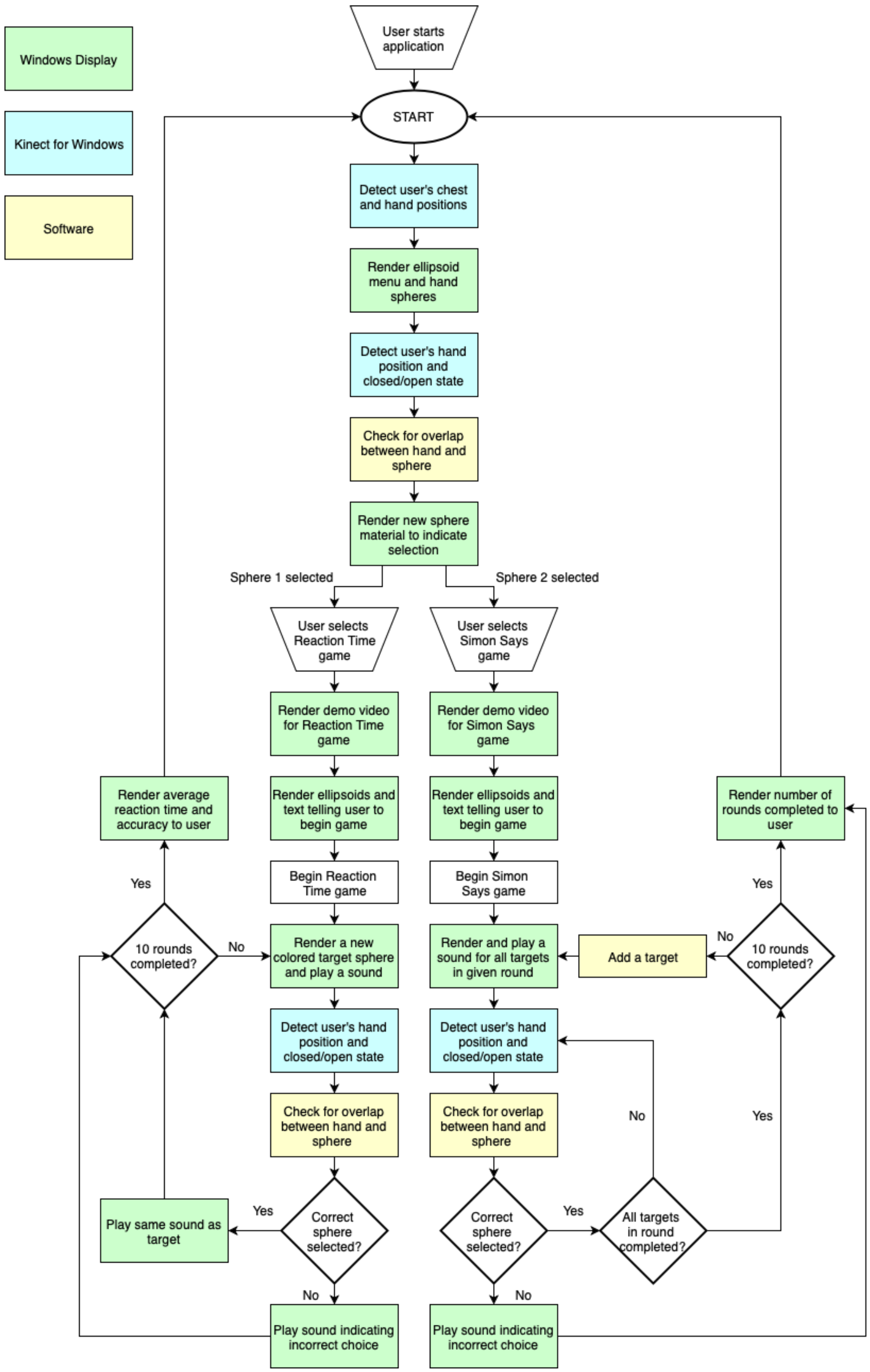


Figure 6: Flowchart of our K.C.P. robot

3.3. Detailed textual description of 3.2. Figures

User starts application

When the user first starts the application, it turns on the Kinect sensor, which serves as an input device for the application. The sensor takes the body positions of the person who is currently using the application. Then, spheres are rendered depending on the position of the user, and since it is locked to the user's body position, the spheres will move in coordination with the user. Collision detection is determined when the hand hits the spheres, so we have hand spheres on the body, and a collision is recorded when the hand is closed while in the determined zone. The position of the spheres relative to the body is based on chest height, so we have chest spheres rendered at the chest position, which the rest of the menu spheres are based on. This allows the spheres to follow the person, so it won't leave their immediate reach. The gamestate of the application is set to menu, and it is correctly labeled on the top left corner of the screen, so you always know what mode or gamestate you are in. There are several scripts being run when the user starts the application, including the game manager, exercise zone manager, collision manager, and menu manager.

User selects game mode from menu

When the user is selecting the game mode, they can pick from the set of spheres that was created when the application was started. These spheres vary in color, and are connected to the participant from the chest point so that it follows them around. Each of the hand spheres deal with our two activities, with and without the demo video. The demo video displays the game with detailed instructions on how to play. Zone selection is dependent on whether the participant's hand is closed, as it selects the zone where their hand is when they close their hand. The color of the zone is grey when a hand is hovering over it, and the color of the zone changes from a dim color to a highlighted version of that same color, depending on the zone selected. Depending on which orb was selected. The application then transitions from the menu to whichever game mode was selected, with or without the demo video. During this time, video and demo scripts are enabled depending on the participants input, and the menu script is disabled.

Demo video

The demo video for either game plays depending on if the user wants to play it or not. The video plays, showing the user how to do the task, along with detailed instructions, and after the video, the corresponding game is shown. At the end, the video script is disabled, and the game script of choice is enabled.

Begin Reaction Time Game

When the reaction time game is started, there is a timer that is set up, after which the game would start. For 10 rounds, there is a random target sphere location given, with their respective colors and sounds, along with a selection timer of 5 seconds to check for a participant response. If the user doesn't select a zone for 5 seconds after the stimulus is shown, it will be counted the same as a miss. As soon as the participant selects a zone, the reaction time is calculated (the time between when the stimulus was shown and when the participant selects the zone). If the correct zone was picked, that zone's corresponding sound would play. If the participant picked the incorrect zone, a different tone will play that signals that the choice was incorrect. The reaction time is added to a list of times, and at the end of this, or the 5 second choice timer, this process is repeated, until 10 rounds have been completed. At the end of the reaction time test, results are displayed, which includes the average reaction time over the 10 rounds, along with the standard deviation. This data is displayed to the user for some time, before the game is considered completed, and the application goes back to the main menu. During this time, the reaction time script is disabled, while the menu manager script is enabled.

Begin Simon Says Game

When the participant chooses the Simon Says game, there is a delay as the application transitions from the menu to Simon Says. At the end of this delay, the game begins. There is a while loop that runs while the participant makes correct decisions, because the game ends when the participant gets one choice wrong. At the first iteration, a random zone is played. When the participant gets that zone correct, it is added to a list of zones that will be played back, to test the participant's memory. At each subsequent iteration, the list of zones will be played before the new, random zone. For each round, all the target zones are rendered for the given round, and are displayed in an interval of 0.75 seconds. The corresponding color and sound are played for each target, and the user has a target timer to recreate the sequence. The timer starts at 5 seconds by default, and for each round completed, 1.5 seconds is added to the timer. After the sequence is shown, the participant selects the sequence of zones with the same selection gestures, by extending their hand over the preferred zone, and closing their hand. The correctness of the participant's choice is checked, and if correct, the zone's sound will play, and the selected zone is added to the sequence for playback.

Another 1.5 seconds is added to the timer, and these actions repeat for as long as the participant gets the correct choices. If the choice was not correct, the game is over, and the participant's statistics for their play-through of the game is shown. The application then returns to the main menu. At this time, the simon says script is disabled, and the menu manager script is enabled.

Technology Overview

We decided to use the Kinect sensor and Unity 3D to implement our project. Unity 3D is a game development platform and engine that integrated very well with the Kinect SDK. Using C# scripting, custom components, and the Kinect Unity package, we were able to easily visualize body tracking and trigger game events.

KinectManager : Interacts with the Kinect sensor and exposes hand and chest tracking data to other scripts

ExerciseZonesManager : Use chest tracking data to render the menu ellipsoids and update their positions to follow the user's position

CollisionManager : Detect collisions between the user's hands and the menu ellipsoids and change the color of the ellipsoids depending on state of that hand (open/closed)

SelectionManager (Reaction Time game) : Game logic for the Reaction Time game

SimonSaysManager : Game logic for the Simon Says game, includes recording

MenuManager : Controls the main menu functionality for game selection

GameStateManager : Controls the switching between different game and menu states

Video_Player_RTI : Plays the demo video for the Reaction Time game before switching control to *SelectionManager*

Video_Player_Simon : Plays the demo video for the Simon Says game before switching control to *SimonSaysManager*

3.4. Detailed description of functional and usability-testing methodology

Both the functionality and the usability of the robot were assessed.
While baseline measures such as the minimum and maximum detectable distance for the Kinect were established experimentally by the authors, most of the evaluation was performed with volunteers.

Six individuals volunteered to test our device (figure 7). The name, age and height of the volunteers were recorded. The volunteers were asked to step in front of the sensor and the session was started. Each individual was given one minute to get accustomed with their environment and the zone design. The users hovered their hands above each zone to ensure that they were within reach.

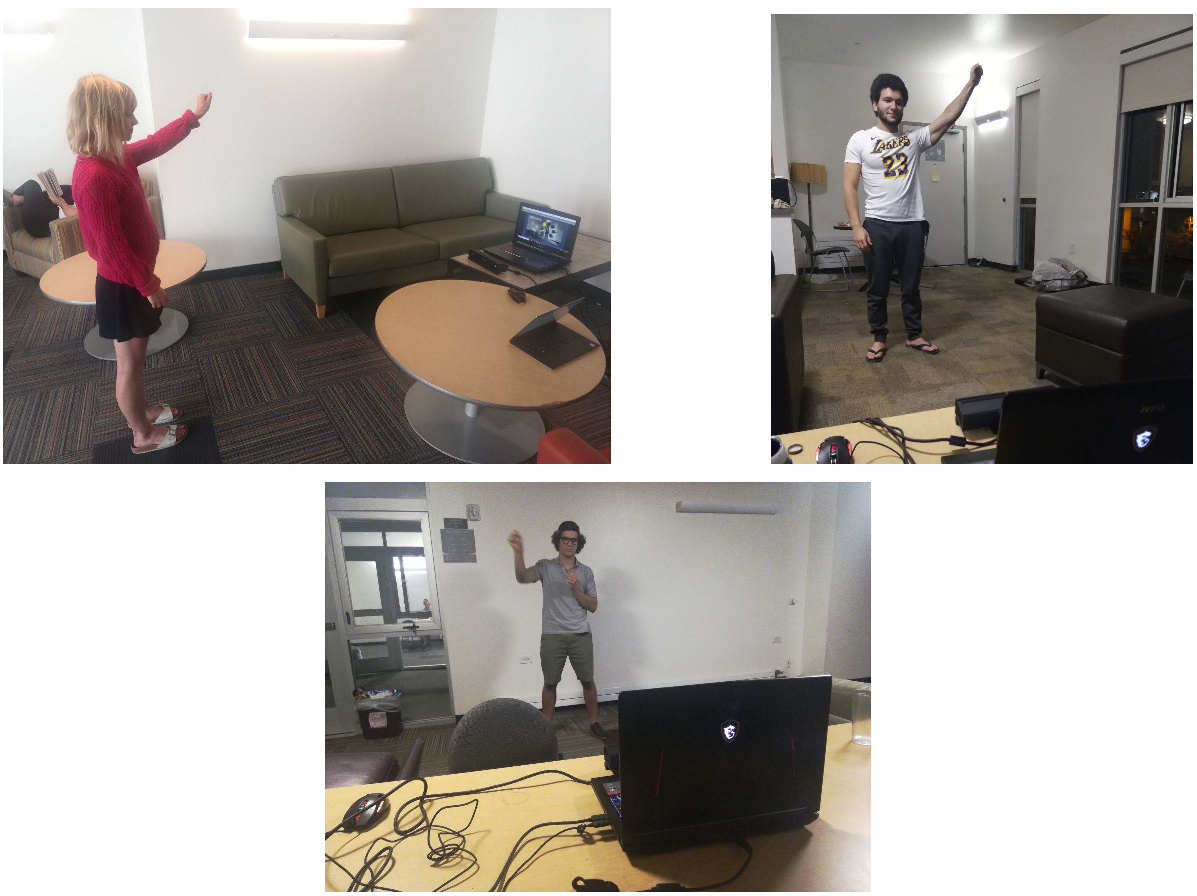


Figure 7: Pictures of some of the volunteers testing K.C.P.

The volunteers were then asked to select the first zone by hovering over it and closing their hand upon collision. The accuracy of the selection was recorded (‘1’ if the user managed to select the zone on the first try, ‘0’ if not). If the zone was successfully selected, the RTI Instruction Video was played, at the end of which the individuals were asked to describe the task at hand and rate the clarity of the video in explaining the test procedure.

The RTI test was then played. Each individual’s reaction time was recorded over 10 iterations. The average reaction time, the standard deviation and the selection accuracy were saved. The volunteers were asked to play an app-based equivalent of the RTI game. The app interface is shown in figure 8. Each volunteer’s reaction time measured with the app was recorded, from which the mean reaction time and standard deviation were calculated.

Figure 8: The app-based reaction time (left) and Simon (right) games used to evaluate the accuracy and precision of K.C.P.

The precision of both RTI tests (Kinect-based and app-based) was evaluated from the mean of the standard deviations obtained for each volunteer. The accuracy of the kinect-based RTI test was evaluated from the percentage error of the mean reaction times for all individuals, averaged over all individuals, by taking the app-based RTI test as a baseline or “reference”:

$$Accuracy\ RTI\ =\ \frac{1}{6}\sum_{i=1}^{6}\frac{(Mean\ RTI\ app)i-(Mean\ RTI\ Kinect)i}{(Mean\ RTI\ app)i}*100$$

The volunteers were asked to rate the kinect-based RTI test in terms of entertainment, and state whether the kinect-based RTI test was more fun than the app.

When back in the menu of K.C.P., the users were asked to select the second sphere corresponding to the Simon game. Again, the accuracy in the selection was recorded. A correct selection of the second sphere caused the Simon instructional video to play. At the end of the video, the users were asked to describe what they would have to do in the Simon game. The accuracy of their description and user ratings for the video were used to measure the quality and simplicity of the instructional video.

The Simon game was then started. The level (round) reached by each individual was recorded. The app-based Simon game was then played, and the results obtained with the two methods were compared to evaluate the accuracy of the Simon game. Again, the accuracy was calculated from the percentage error, by taking the app-based game as a reference:

$$Accuracy\ Simon\ =\ \frac{1}{6}\sum_{i=1}^{6}\frac{(Simon\ level\ app)i-(Simon\ level\ Kinect)i}{(Simon\ level\ app)i}*100$$

Due to the limited amount of time, the Simon game could not be played repeatedly, thus its precision could not be evaluated.

The volunteers were asked to rate the kinect-based memory test (Simon) in terms of entertainment, and state whether the kinect-based Simon was more fun than the app.

Finally, the individuals were asked to rate the GUI and the difficulty of the exercises in terms of physical activity. The volunteers were asked to state how often they would use the kinect-based tests, and whether their grandparents were likely to use the robot.

The testing methodology is summarized in table 1.

Module	Description	Evaluation Method	Metric
Motion detection	Detect presence of user	Approach robot from varying directions and distances	Max/min distance, detection ratio
	Detect and identify user movements	Ask volunteers to select a given sphere	Accuracy
Prompts	GUI	Ask volunteers and stakeholders to assess quality of GUI	Individual impression and preferences
	Instructional Videos	Ask volunteers to look at instruction video, describe what they need to do and rate the video	Accuracy in describing task, individual impressions and preferences
Test design	Robot provides an enjoyable and useful workout to the user	Ask volunteers and stakeholders to assess the quality and difficulty of the exercises	Individual impression and preferences
	Cognitive tests provide an enjoyable experience to the user	Ask volunteers and stakeholders to assess the quality of the tests	Individual impressions and preferences
	Tests measure cognitive capabilities accurately and reliably	Compare cognitive assessments obtained with our robots to app-based equivalents	Repeatability (precision), accuracy
	System accuracy	Complete exercises well and poorly on purpose to gauge system feedback	Accuracy, success rate
	Usable by anyone	Ask volunteers of various genders, heights and ages to use the robot	Success rate

Table 1: Functionality and usability testing method

4. Results

First, the sensing range of the Kinect was established. The minimum and maximum distances at which the Kinect would reliably identify the user's skeleton were found to be equal to 1m and 4m respectively, thus confirming that our robot could be used in a home setting. However, the tracking ability of the kinect was affected by lighting conditions, with bright direct light causing inaccuracies in movement detection. Therefore, all exercises were performed indoors when K.C.P. was tested with volunteers.

All volunteers were able to reach the zones, irrespective of their height (153cm to 188cm). All volunteers accurately selected the menu selection zones in their first attempt, resulting in an accuracy of 100% for movement detection and identification. The robot could also identify purposeful erroneous selection with an accuracy of 100%.

All volunteers stated that both instructional videos were well explained and simple to understand, with an average rating of 9.75/10 being given for the quality of the videos. All individuals were able to accurately explain the task at hand.

The precision (standard deviation of the measurements) of the kinect-based RTI was found to be equal to 0.199s, compared to 0.15288s with the app. The mean reaction times achieved by each volunteer with the Kinect-based and app-based RTI tests are shown in table 2, and corresponded to an accuracy of 12.53%.

Volunteer #	RTI Kinect mean (s)	RTI App mean (s)	Simon Kinect (round)	Simon App (round)
1	0.70	0.60	14	12
2	1.16	0.65	8	7
3	0.64	0.79	13	10
4	0.82	0.70	12	7
5	0.70	0.83	22	23
6	0.71	0.70	9	10

Table 2: Evaluation Results

As this point, it should be noted that some of the discrepancies can be attributed to the differences in test design. Indeed, in the app, only 4 zones were shown (compared to 7 in K.C.P), and the prompts were shown in different forms: zone number, zone color, zone position. These prompts differed from the simple zone color and sound prompt that was used for K.C.P.

The level reached by each individual on Simon are shown in table 2, from which an accuracy of 12.65% was calculated. Again, discrepancies might be due to the different number of zones being displayed for the app (4) and the Kinect (7).

All volunteers found K.C.P. more fun than the RTI and Simon apps, with an average rating of 8/10 for both tests. The GUI was given an average rating of 8.5/10.

The difficulty of the exercises was evaluated at 3.5/10. All volunteers completed the exercises effortlessly, and stated that they did not have the impression of exercising. However, all individuals recognized that the types of motions and exercises required by the tests were adapted for older adults, for whom the difficulty of the exercises was estimated to 7/10.

Finally, while 4/6 volunteers stated that they would use K.C.P. daily, 5/6 stated that their grandparents were unlikely to use the robot, mostly due to the technology barrier.

Additional feedback from the volunteers allowed us to assess the usability of our robot. All volunteers found that the combination of color and sound was particularly useful in identifying the target sphere. For the Simon game in particular, the sound appeared to be the most helpful prompt for memorizing the sequence, while color was necessary for identifying the target zone.

5. Discussion and Future Work

After the first cycle of development for our project and some initial user testing, we are able to report several successes. Our project yielded very similar quantitative results to previously established cognitive tests and was highly enjoyed by our testing population. As a result, we are confident that our project could be used as effectively as such tests to detect early signs of dementia and evaluate cognitive performance and short-term memory.

We were also successful in effectively combining a cognitive task with a physical exercise component. While this made it slightly more difficult and inconvenient for users to use than the app-based equivalent cognitive tests, it did encourage and require the user to complete light to moderate exercise.

However, despite these successes, there are many more things that we would have liked to have had the opportunity to do with our project. In the future, with more time and resources, and a clearer overall project vision, we would love to see some of the following steps be taken.

The next essential step in product development would be testing with actual stakeholders from our target user group. Getting feedback from older adults, individuals diagnosed with dementia, or persons recovering from stroke would be a huge benefit to improving the design of K.C.P. Involvement early and often and including our stakeholders throughout the iterative design process would ensure that what we create would be actually useful, intuitive, and effective. Our testing population consisted of only younger adults at university who were physically capable, experienced with technology, and without severe vision or hearing impairments. Testing with an expanded set of users would yield much more meaningful feedback.

Additionally, we would want to see more options and customizable settings be built into the product. Examples include allowing users to select color and sound options, implementing different ways to indicate selection (grasping vs timed overlap), and calibrating the menu ellipsoids to be rendered according to the user’s height and arm length.

We also would want to expand our set of game modes to go beyond just upper-limb and hand grasping physical exercises. In the spirit of ability-based design, increasing the capabilities and scope of our project to include stakeholders with varying levels of ability and body control is of high importance. At this moment, our project is only robust for users who are able to stand up on their own for the duration of the exercise. We would really like to develop a robust experience for users who are sitting or being supported by a cane, walker, or another person.

We would like to see these changes and extensions reflected in future iterations of K.C.P. design and believe that they have the potential to positively impact our stakeholders.

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