Investigating the Usability of the Leap Motion Controller:

Gesture-Based Interaction with a 3D Virtual Environment

Final Report

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Abstract

The Intelligent Tutoring Group at the University of Canterbury has created a 3D virtual environment for stroke rehabilitation, specifically, training the prospective memory in a safe and familiar setting. This honours project involved the creation of a gesture-based interface via the Leap Motion for navigation and interaction within this environment, in the 3D game creation engine Unity. A study was undertaken in which 30 participants used the Leap Motion to interface with the environment with different modes of interaction and data was gathered from their performance as well as from a questionnaire they completed. Feedback from the study has been positive with many participants claiming this form of control to be more user friendly and intuitive than more traditional devices. The data collected suggests that certain modes of gesture-based navigation and interaction are better suited for interaction with the environment.

Acknowledgements

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1 Introduction

1.1 Project Summary

The Intelligent Computer Tutoring Group (ICTG) at the University of Canterbury (UC) have created a 3D virtual environment for stroke rehabilitation, specifically, training prospective memory in a safe and familiar setting. A gesture-based interface via the Leap Motion controller is proposed for navigation and interaction within this environment.

1.2 Project Background

Strokes are currently a large health concern and a heavy burden on populations all over the world. Strokes are the third highest cause of death in developed countries after heart disease and cancer [1]. But they are also responsible for a range of physical and mental disabilities which can have long term socioeconomic effects and are the leading cause of adult disability [2]. Although the incidence of strokes has declined in recent decades, the fact that the prevalence of strokes is much higher in the elderly, coupled with an ageing population and higher life expectancies, has meant the lifetime risk of having a stroke and the overall number of strokes occurring have not decreased in equal proportion [2, 3].

Prospective Memory (PM) is the ability to carry out previously planned tasks at a specific point in the future [4]. There are two types of PM-based tasks: event-based and time-based tasks. An example of an event-based task would be to 'make a cup of tea once the kettle has finished boiling' while an example of a time-based task would be 'at 7:00 am go outside and collect the newspaper'. PM can be adversely affected by strokes and other traumatic brain injuries. Failure in this area of cognitive ability can range from being an annoyance to being life threatening, affecting the level of care a stroke patient might need [5]. Fortunately, there is the potential for PM rehabilitation and training, and the ICTG aims to address this with their environment [4].

Gesturing as a method of Human Computer Interaction (HCI) is a relatively new and evolving field. Gesturing is a natural part of everyday communication in humans and it has been demonstrated that young children gesture before they learn to talk. This natural form of communication is now enabling a wide range of people, such as the elderly and disabled, to interface with computers. This kind of interfacing has also grown easier as technologies have evolved, becoming cheaper and more widespread [6].

The Leap Motion is a new device for gesture-based interaction, only released commercially in late 2013 [7]. The device itself is only 0.5 by 1.2 by 3 inches and connects by USB to a computer. To use it, the user places the device in front of them and gestures above it. Its field of view is 150 degrees and its field of tracking is a hemisphere over 2 feet above the device and 2 feet from the sides. Its designers claim it to be able to track all ten fingers concurrently to an accuracy of a hundredth of a millimetre with a sampling rate of over 200 frames per second [8]. The Leap Motion can be seen in Figure 1.1. In an independent study it was found that static measure of positions could be achieved to less than 0.2mm accuracy and discretely tracking an object through a path to less than 0.7mm accuracy [9]. This is not as impressive as claimed on the Leap Motion site but still better than the achievement of the Kinect device (1.5cm static accuracy) and what the human hand can achieve (0.4mm static accuracy on average) [9]. Another study also found inaccuracies in the controller, particularly above a height of 250mm [10]. They also found the sampling frequency to be inconsistent and mentioned this could lead to difficulty in synchronising the controller with other real-time systems. Information on the cameras the Leap Motion contains and the data it retrieves can be found in the Implementation chapter.

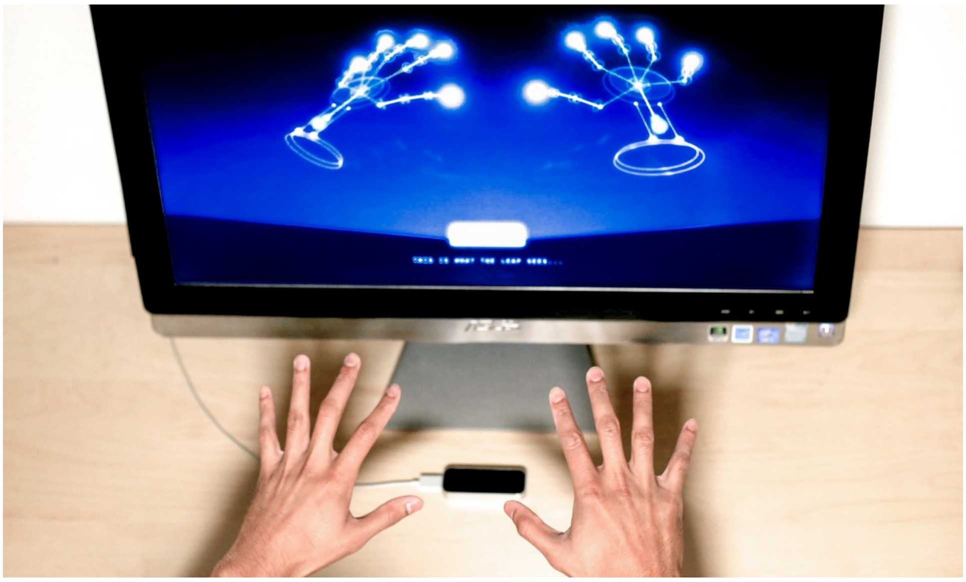

Figure 1.1: The Leap Motion[1]

The 3D virtual environment developed by the ICTG is a house which is filled with various standard household rooms and objects that can be picked up and/or interacted with [11, 12]. The training involves stroke patients navigating around the house and completing a series of prospective memory based tasks such as 'when it begins to rain, take the clothes from the washing line inside' or 'at 6:00 pm, turn on the television to watch the news'. Navigating the environment involves being able to move forward and backward and rotate left and right. Also, users need to be able to check the current inventory of items they have picked up, check the time and be able to crouch. Users must also be able to use simple GUI menu elements in the environment. One scene from the environment can be seen in Figure 1.2.

[1] Source: http://mashable.com/2013/06/24/leap-motion-airspace/

Figure 1.2: The ICTG Environment

The ICTG have considered various methods of interaction with the environment. Currently a joystick is used for navigation and its trigger for interacting with objects. The 'i', 't' and 'c' buttons on the keyboard are used to check the user's inventory, check the time and crouch respectively. The environment is constructed in Unity 3D, a powerful and popular 3D virtual game development platform [13]. A Software Development Kit (SDK) for development with the Leap Motion already exists and can be easily imported as a plugin to Unity 3D, greatly reducing the development time required to integrate the Leap Motion into the environment [14].

1.3 Related Work

Davidson has investigated gesturing as a means of interaction with a 3D environment [15]. This work was predominantly done with Microsoft's Kinect controller, which can recognise full body movements. One of the largest problems with their work was that the Kinect could not pick up fast and fine-tuned movements. While the scope of movement with the Leap Motion is smaller, its tracking capabilities should be a significant gain in this respect. Davidson also mentioned the fact that the non discrete nature of gestures can cause issues when large sets of controls are required as there can be overlap between them causing interference between the gestures. An open ended choice system was used in their environment, so users could actually have some choice over what gestures corresponded to particular actions but did not recommend this approach as this made it difficult to acquire measurements and preferences of individual gestures.

Nabiyouni, Laha and Bowman conducted a study with the Leap Motion [16]. They looked into various aspects of usability, such as unimanual and bimanual techniques, airplane and camera-in-hand metaphors, camera movements and speed control methods. For the bimanual approach, they made sure that the dominant hand was used for steering, since it is a more precise task, and the non dominant hand used for speed control. Both of these aspects were condensed into the one hand for the unimanual approach. For the airplane metaphor, the forward direction was the current orientation of the camera, and rotation of the user's hand would cause the camera to rotate on the spot. The camera-in-hand method would map the user's position in the Leap Motion's workspace directly to the virtual world, so moving the user's hand would actually move the camera directly around the environment, including rotation and translation. For this project, the airplane metaphor is the most applicable since the camera will display the view a person would perceive. The size of the environment is large with obstacles such as doors that need to be navigated, which is out of the scope of the camera-in-hand method. Nabiyouni, Laha and Bowman tried three methods of speed control. First they based the speed on the number of fingers visible, which is a discrete method. Next they tried using the thumb as an indication of speed, which gave a continuous range of speed. Finally, they used a gas pedal metaphor, where the angle of the hand would change the speed analogous to a gas pedal in a motor vehicle. This was another continuous form of speed control.

For Nabiyouni, Laha and Bowman's study they selected five methods. Four used the airplane-metaphor approach: unimanual with thumb speed control, bimanual with gas pedal speed control, unimanual multi-finger speed control and bimanual multi-finger speed control. The fifth used the camera-in-hand metaphor with unimanual control. They used three different tasks to assess their implementations. The first was to travel from a starting position to a target position. The second required users to search for and find objects in a set amount of time. The third task was to follow a specific path passing through rings as they travelled. The researchers found significant differences between techniques and made some general observations on their results. They found that participants faster when using the camera-in-hand metaphor, than the four airplane metaphor methods, for all three tasks. But the airplane metaphor was more precise, and users were more accurate in traversing the hoops in the third task. This was due to the fact that the task required precise trajectory control. They also concluded that the continuous speed options provide a better user experience, based on user opinions and their own experiences. Additionally, they found that the Leap Motion's ability for precise tracking of small movements benefitted the usability of speed control. They did encounter some issues during their study. Firstly, tracking may be lost by the Leap Motion when there is 80 degrees or more pitch or roll in the orientation of the hand. Secondly, when fingers are next to each each other or cross over, the Leap Motion may track them as a single finger. Lastly, user fatigue in the arms was an issue.

Fanini created a 3D interface with the Leap Motion for interacting with a 3D virtual environment [17]. Their goals were to provide an efficient and fast interaction model. The environment only involved a single room with objects at the center which the user could interact with, so there was not much focus on the navigational aspect of the navigation. There were two distinct states that the interaction interface could be in. In the first, the Leap Motion workspace was mapped directly to the environment, which was possible since there was only one room, and the camera could be moved directly around in similar fashion to the camera-in-hand metaphor method in the previously discussed study. In the second state the user could no longer move the camera position but could now interact with objects. The user's hands would appear in the environment as skeletal-like models, left hand blue and right hand red, which could then pick up objects and manipulate them. To alternate between the two states, a specific dragging gesture is used. As the researchers found fatigue to be a problem, it was envisioned that the user could rest their arms during the second state to reduce fatigue. Another issue they encountered was the loss of tracking of the hands by the Leap Motion when the hands neared the edge of the field of view, which they combated by implementing smoothing filters to the received data at the software level. As there is both movement and object interaction in the ICTG environment, a two state approach could be a plausible method of interaction.

1.4 Research Questions

These are some of the specific questions investigated in this project:

- Can gestures be a viable method of navigation and interaction with a virtual environment?
- Is the Leap Motion controller a viable device to accomplish this?
- How will the Leap Motion compare with more traditional devices such as a keyboard and mouse combination or joystick?
- What specific set of gestures are the most natural, intuitive and user friendly?
- Are there other factors that affect how natural, intuitive and user friendly someone finds the system?
- Will there be any specific problems associated with using the Leap Motion, such as fatigue from using the device or impreciseness in its tracking capabilities?

2 Method Outline

2.1 Implementation Outline

The first step was to integrate the Leap Motion into the environment created by the ICTG in Unity using the available SDK for the Leap Motion. Next was to assess the Leap Motion's capabilities and implement a system of gesture-based navigation and interaction. The methods of interaction and navigation implemented were influenced by related work reported in the literature review and were aimed at being easy to use and intuitive. This part of the project was aimed at assessing if a fully gesture-based system of interaction could be created for the environment with the Leap Motion and revealing any problems that might arise from such a system and the Leap Motion itself. The result of this stage of the project was that a system of gesture-based interaction was implemented that provided all the required functionality and three modes of navigation were implemented with several issues with the Leap Motion identified and overcome. Initially, the spacebar was used to achieve some of the required functionality but users found the use of an extraneous device to be irritating and so the use of the spacebar was replaced with a gesture which became available after an update of the Leap Motion SDK. The actual implementation is discussed in detail in the following Implementation chapter.

2.2 Studies Outline

A small pilot study was carried out by experts to assess the system by having them navigate and complete tasks within the environment. Based on the results and feedback from this pilot study adaptions were made to the system. A main study was constructed and carried out involving more participants. During the pilot study and the main study, measurements of performance were recorded while the tasks were completed and a questionnaire was also presented to the participants to fill in upon completion. The system was set up so that a participant of the study could test the functionality of each of the three implemented navigational modes. An information sheet explaining the study and a consent form were given to potential participants of this study (see Appendices A.5 and A.8). Participants were primarily recruited from current Computer Science and Software Engineering students by visiting lectures and recruiting the students directly. The aim from this study was to retrieve feedback from the participants on what they found easy/difficult, intuitive/unintuitive, generally assess the system and identify any further problems. Also a comparison of the different modes of navigation was hoped to be made from the participants feedback and from the data recorded as they were using the system.

In addition to these two studies another pilot study with an actual stroke patient was run. Originally, it was envisioned that possibly more stroke patients would test the system but this was beyond the scope of this research as the larger ICTG has had much trouble recruiting participants for their studies with the 3D environment, as this must be done through a third party. The three studies are described in detail in the Studies chapter.

2.3 Analysis

The data that was recorded was objective and involved measurements such as the time taken to perform tasks, number of times the time and inventory are checked and the amount of time spent crouched. The questionnaire involved demographic questions such as gender and age as well as subjective questions based on the Likert scale. They were also asked to rank the various methods against each other and to comment on what they found difficult or beneficial about the various methods. Information was also gathered by observations during the studies such as common features which caused frustration to many of the participants.

The data gathered from the recorded information during the main study, questionnaires and observations was then used to compare the modes of interaction. At first, gesturing was used in conjunction with the space bar on the keyboard, but this was later removed due to feedback from participants and the system is now fully gesture-based. It is hoped that results from this project will not just be specific to just the ICTG virtual environment and stroke rehabilitation, but in general for gesture-based interaction with virtual environments.

3 Implementation

The term ‘user’ refers to someone who is currently using the Leap Motion to interact with the environment. In this report, the term ‘agent’ refers to the character that users are actually controlling within the environment via their interaction.

The Leap Motion works by emitting a 3D pattern of dots of IR light from its three LEDs which is then received by its two cameras. This raw data is then preprocessed before being available through the Leap Motion software. The raw data is not explicitly available, only the preprocessed data is available and is what the Leap Motion developers have specified on their Application Programming Interface (API) [14]. This data is what was used to implement the system and is referred to as being ’from the API’ in this section. This data is accessed by creating a ’Frame’ object in the code and querying the required properties from it each frame. These properties include information such as:

- Hand position: x, y and z positions
- Palm angles: pitch, roll and maw
- Individual finger information
- Detected gestures
- Grip strength (introduced in SDK version 2)

As well as many more properties. More properties also become available after updates to the SDK. The following Leap Motion defined gestures are gestures that are directly available from the API, so in a given frame the Leap Motion could be queried to see if it had detected one of the gestures, of which there were four available in total:

- Circle Gesture
- Swipe Gesture
- Screen Tap Gesture
- Key Tap Gesture

All work done on the implementation of the system was done at the University of Canterbury on a desktop PC running Windows 7 Enterprise 64 bit with an Intel i7-3770 3.40 GHz quad core CPU, 16GB RAM and an NVIDIA GeForce GTX 760 4GB memory GPU

3.1 Leap Motion Integration With Unity

The first step involved reading documentation on how to the correctly set up the Leap Motion to work within Unity. This involved downloading and installing various packages and reading the documentation on the interface that these packages provided for the Leap Motion. Two DLL files contained the interface with drivers that controlled the Leap Motion USB input and would communicate with Unity to deliver the preprocessed data that the developer would use. A plugin released by the Leap Motion developers was available in Unity that contained all the boilerplate code to get the functionality described in the API.

3.2 Leap Motion Integration with the Environment

3.2.1 Non-Navigational Controls

The term 'Non-Navigational Controls' in this case refers to actions which do not move the agent within the environment but accomplish other stationary functionality.

Crouching

To accomplish some tasks in the environment, the user needs to be able to make the agent crouch. For instance, when using the washing machine, the agent must be crouched down to a level where they can interact with it. This was implemented by making the user lower their hand and return it to its neutral position to crouch, and by raising their hand and returning it to the neutral position to un-crouch. This was done such that crouching/un-crouching could not occur in quick succession to stop the agent immediately un-crouching after crouching when the hand returns to the neutral position and vise versa. If the current navigation method involved two hands, the dominant hand would be used for crouching. This functionality was achieved by the following steps:

1. A queue would be initialised to hold 40 values of the hand's current height.
2. Initialise a timer.
3. Each frame, deque a previous value from the queue and retrieve the hand's current height value and enqueue it to the queue. These two values will be referred to as *current* and *previous*.
4. If two seconds have have passed since the last timer initialisation, continue, else, return to step 3.
5. If $current < \frac{previous}{2}$ (is the current height is less than half that of 40 frames ago?) or $current - previous < -80$ (is the current height is less then eight centimeters than the height 40 frames ago?), flag that a crouch action has occurred, initialise the timer and return to step 3.
6. If $previous < \frac{current}{2}$ or $previous - current < -150$, flag that an uncrouch action has occurred, initialise the timer and return to step 3.

7. Return to step 3.

It was found through early experimentation that users would usually raise their hand further for uncrouching than they would lower their hand for crouching, hence the difference in values for detecting crouching versus uncrouching. This is most likely due there being not much distance from the hand to the Leap Motion, so not much space to move the hand down as the hand would hit the device itself or the desk, but no such restriction on the movement of the hand upward for uncrouching.

State Changing

The user also needed to be able to interact with objects in the environment. A two state scheme was implemented, as described by Fanini [17]: the navigation state and the interaction state. In the navigation state the user could navigate the agent through scenes as described below in the Navigation Controls section. In the interaction state, the user could interact with objects.

To alternate between the two states, one of the Leap Motion defined gestures was used; the Circle Gesture as mentioned earlier. To invoke this gesture, the user had to rotate a single finger in a circular gesture. Unfortunately, this gesture was inconsistent, not only frequently failing to pick up the gesture but also frequently generating false positives, causing unnecessary and annoying state changes. A dialog box was implemented that displayed the current state that was activated. This would help a user identify when a state change had occurred, to mitigate problems caused by any false detection of the 'circle gesture'. A timer was also implemented that prevented quick state changes; at least a second must have passed before the state can be changed again. This was also required as a particular gesture would be detected over several frames by the Leap Motion software, not just one in frame, so one gesture would cause several instantaneous state changes without this kind of blocking mechanism. A second timer was also created that ensured a particular gesture was detected over a certain amount of time, specifically, 0.2 seconds. This was to help prevent false positives by requiring the gesture to be detected over several consecutive frames, and detection of the gesture in just a single frame would not cause a state change. This functionality was achieved with the following steps:

1. Initialise two timers: $lastStateChange$ and $currentDetectionTime$
2. Each frame, query if the gesture has been detected. If so, add the current frame time to the $currentDectionTime$ and continue (the frame time is the time it has taken this frame to be processed, so running at 40 frames per second, this would be 1/40 of a second). Else, no gesture is detected, so reset the $currentDetectionTime$ to 0 and repeat step 2.
3. If $currentDetectionTime$ is greater than 0.2 seconds and 1 second has passed since $lastStateChange$, continue. Else, return to step 2.
4. Reset the $currentDetectionTime$ to 0, set the $lastStateChange$ to the current time and toggle the state.
5. Return to step 2.

Also, the behaviour of pressing the spacebar differed depending on what state the user was in. If the in the navigation state, pressing the spacebar would bring up the action menu (described below) while if they were in the interaction state, the action control would interact with an object, if one was selected (described below).

In the final version of the system, for two reasons, the state changing functionality was dropped entirely. After the first pilot study, it was decided that, as well as being very unreliable due to the inconsistencies of the Circle Gesture provided by the Leap Motion API, having to consistently change state states was overly clumsy. For instance, to open a door, the user would navigate the agent to the door, change state to the interaction state, open the door, change state back to the navigation state, then proceed. This was unintuitive and caused the user to have to stop and consciously think of what actions to take to accomplish this task. Instead, the system checks what context the agent is currently in. For example, if the user is currently facing and close to an object and presses the spacebar, then the user most likely wants to interact with the object. Otherwise, if no object is present when the user presses the spacebar, the user most likely wants to bring up the action menu (described below). Also note that the use of the spacebar for this functionality was later changed, as mentioned in the Removal of Spacebar section below.

Object Interaction

Interacting with objects was originally envisioned to be done with one of the Leap Motion's predefined gestures, the Screen Tap Gesture mentioned earlier, in which the user would point a single finger forward and return it to activate. Unfortunately this gesture, like the Circle Gesture before it, was also extremely unreliable, often not being detected and worse, frequently being falsely detected. Instead, an additional button was used for this task: the space bar on the keyboard. Therefore, if the user wanted to interact with a particular object, they would need to navigate the agent so it was looking directly at the object while being close to it, which would cause the object to become highlighted red, then the user can hit the space bar to interact with it. To find what object the agent is looking at, a ray would be cast of the the current camera position and if it collided with an object before a certain distance, that object would become red and highlighted. Some objects will activate automatically once being interacted with, such as doors opening and closing, and others will open a menu that shows furthers options, such as a washing machine with which the user can turn on/off or add and remove items from. Also note that the use of the spacebar for this functionality later changed as mentioned in the Removal of the Spacebar section. A picture of an object being highlighted red and interacted with can be seen in Figure 3.1.

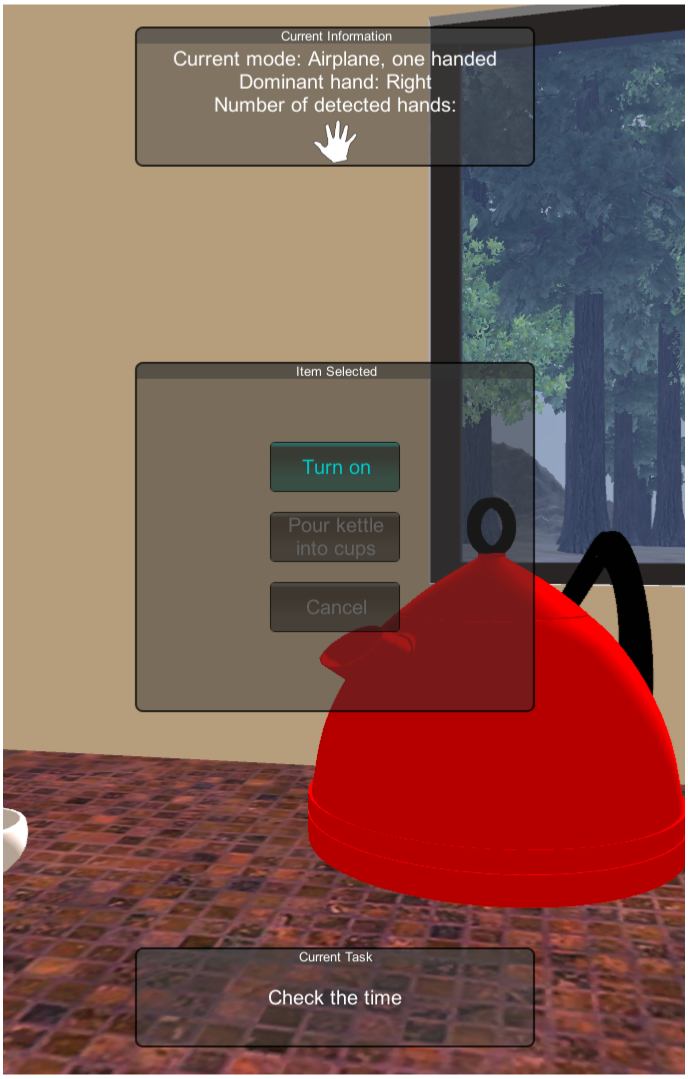

Figure 3.1: Interacting with an Object

Action Menu

Before the menu implementation to access the inventory, time and current tasks was implemented an attempt was made to access these items by displaying a certain amount of fingers. Specifically, one finger, two fingers and three fingers used to access the inventory, check the time and view the current tasks respectively. This was to negate the need for a menu system altogether. Unfortunately, detection of individual finger was very unreliable. An outstretched palm with fingers together would normally be detected as a single finger, rather than no fingers or all fingers, which meant when one finger was displayed by itself, no change would occur. Also, there was too much variance in detected fingers for this approach to be successful, for instance, two fingers being displayed would often be detected as one or three fingers.

In the environment users also need to be able to check their inventory, the time and the current tasks. The current tasks is a list of all the tasks that need to be completed in a given session, with the current active task highlighted. For the implementation, when the space bar (later replaced with a gesture) is pressed and no object is currently in range of the agent, a menu is displayed in which the inventory, time and the current tasks are available to choose from, plus a cancel button. Once this menu is activated, all other movement is suspended, so the user can not mistakenly move the agent whilst navigating the menu. The method of menu navigation and selection is discussed below. A picture of the Action Menu being displayed is shown in Figure 3.2.

Figure 3.2: Using the Action Menu

Menu Navigation

When certain objects are interacted with, a menu appears displaying several options. For example, when the washing machine object is interacted with, a menu is displayed with options to turn it on or off, put an object inside, take an object out or cancel to exit the menu similar to the menu displayed in Figure 3.2. Also the Action Menu mentioned above needs to be navigable. To navigate these menus, a method was implemented so the user could tilt the pitch of the dominant hand up or down to move the selected menu item up or down. The Leap Motion specifically measures the tilt of the palm and not the tilt of the fingers, so the user would need to ensure that the tilting action begins at the wrist. This was implemented as discrete movements, meaning the hand would have to be returned to neutral position each time so multiple movements of the selected menu item could not be triggered by a single gesture. These menus were also implemented to wrap around, meaning that navigating off the top of the menu cause the selected menu item to now be the bottom item. Selection of items within the menu was originally done with the spacebar, but this functionality was changed as mentioned in the section below.

The detection of the pitch was implemented with a dead zone, so the hand angle would need to be above a certain amount to facilitate an upwards movements and below a certain amount to facilitate a downwards movement. The downwards and upwards menu navigation plus selection were implemented with a blocking system to achieve the discrete functionality required. For instance, the downwards functionality would behave as follows:

1. Initialise a *blocking* variable to true.
2. Each frame query the palm angle. If the $angle < 25$ degrees, continue. Else, set *blocking* to false and repeat step 2.
3. If *blocking* return to step 2, else, continue.
4. Move current menu focus down one element, set *blocking* to true.
5. Return to step 2.

Similar behaviour is implemented for upwards menu navigation and menu item selection. A picture of the kind of menu users need to navigate can be seen in Figures 3.1 and 3.2.

Removal of the Spacebar

Originally, it was envisioned that the system be dependent on the Leap Motion only with no external controls, but the spacebar was adopted for object selection, bringing up the Action Menu and menu item selection. This was due to the need for a discrete action to make these events occur and the Leap Motion defined gestures available through the API were unreliable at best. After receiving feedback from the main study, as discussed in the Discussion chapter, another gesture-based method was looked for to replace the need for the spacebar, as many users had commented negatively about its use. The Leap Motion SDK had been updated and and new functionality existed through the API to detect if the hand was closed or not. The keyboard action was removed and replaced with a hand closed action instead. This was the functionality that was used for the final pilot study involving the stroke patient. The resulting functionality follows the following steps:

- Initialise a *blocking* variable to true
- Each frame, if the hand is detected to be in a fist, continue. Else set *blocking* to false and repeat step 2.
- If *blocking* return to step 2.
- If agent currently looking at an object, activate that object. Else, activate the Action menu.

Blocking is required due to stop some object interactions occurring each frame. For instance, if the user is to open a door by closing their hand, blocking is needed until their hand is open again or the door will be continually activated as the closed hand is continually detected, opening and closing the door each frame repetitively until the user opens their hand. The closing hand gesture is also used to select items within the Action Menu and object interactions menus.

3.2.2 Navigation Controls

To begin with, modes of navigation were adopted as discussed by Nabiyouni, Laha and Bowman [16]. Four different navigational modes were trialed: discrete mode, airplane metaphor mode, airplane metaphor plus gas pedal metaphor mode and positional mode. After the pilot study, it was decided that only rotational or forward/backward movement should occur, and not simultaneously. So the end result is that if just forward/backward movement is detected, move the agent forward/backward, but if just rotational movement is detected or rotational movement and forward/backward movement is detected, rotate the agent. This implies that rotational movement takes precedence over forward/backward movement.

Discrete Mode

A discrete mode of navigation similar to the one Nabiyouni, Laha and Bowman described was the first to be implemented. The aim of the mode was to have the agent move forward in the environment based on the number of fingers the user was holding out. For example, forming a fist would cause the agent to be stationary and extending one finger would the cause agent to move forward, with increased speed as additional fingers were extended. Unfortunately the Leap Motion was inconsistent in detecting individual fingers as mentioned earlier, often detecting the closed fist as a single finger itself and had trouble detecting the thumb. Due to these inconsistencies, the use of individual fingers as controls for the Leap Motion was dropped. For these reasons a discrete mode of navigation was not implemented.

Airplane Metaphor

This mode is implemented for just one hand, the user's dominant hand, with the pitch of the hand controlling the forward and backward movement and the roll of the hand controlling the rotation of the agent. A dead zone for both forward/backward and rotational movement was implemented where the angle of the hand would have to pass certain threshold before the movement would being. This was so the user could easily find a position of stability where no movement would occur without having to get the position exact. Once movement had begun, the larger the inclination of the pitch or roll of the hand, the faster the respective movement and rotation.

Airplane Plus Gas Pedal Metaphor

In this mode the roll of the dominant hand of the user controls the rotation of the agent while the pitch of the non-dominant hand controls the forward and backward movement. Again, dead zones were implemented as discussed above. So essentially the non-dominant hand can be thought of like a gas pedal since as the user tilts it forward the agent begins to move forward. The dominant hand controls the rotation similar to the previous mode, the reason for rotation being on the dominant hand is that it is considered a more complex form of movement, as mentioned by Nabiyouni, Laha and Bowman [16].

Positional Mode

The last mode to be implemented was a positional movement mode using a single hand. Moving the hand forward/backward and side to side would cause the agent to move forward/backward and rotate side to side respectively. This mode was based on the physical position of hand with respect to the Leap Motion rather than just the inclination of the hand, as in the last two methods. Again dead zone were used to create a region of stability where no movement would occur, in this case, a 5 by 5 centimeter box centered around the Leap Motion.

3.2.3 Non-Action Implementations

Non-action implementation refers to functionality within the system that does not involve the user's participation.

A dialog box was implemented to display information at the top of screen. This box contained information on the current navigation method being used, what the dominant hand was set to and how many hands are currently being detected by the Leap Motion. It had also contained the current state before state changing was removed. The number of hands currently being detected is important, as the one-handed navigation modes only allow commands to be executed when exactly one hand is detected, and two hands for the two-handed mode to stop unintended commands being carried out. If two or more hands are detected in the single handed modes, the system would know which it should be taking its commands from. The dominant hand is important to know when in the gas pedal plus airplane metaphor mode as the hand that acts as the gas pedal and the hand that acts as the airplane are decided by which hand is considered dominant. An example of this dialog box can be seen in Figures 3.1 and 3.2.

3.3 Problems with the Leap Motion

Aside from the problems mentioned previously in this chapter, other non-implementation specific problems occurred. One frustrating problem with the Leap Motion was the detection of extraneous objects as additional hands. This included wristwatches, sleeves and, amusingly, the user's face. To prevent this, users were asked to roll up any sleeves they had remove any bracelets or wristwatches they were wearing. No issues were detected with rings on user's fingers. Also, any detected objects that were more that 20cm from the

Leap Motion towards the user were culled, to prevent the cases where the user's face was detected as a hand. As mentioned in the above sections, the timers were used extensively to prevent false positives, of which there were many for many different types of actions, by ensuring the actions were detected for multiple consecutive frames before being executed.

During the main study on many occasions the agent would suddenly begin spinning at the maximum rotation speed. This only occurred in the two airplane metaphor modes. No cause could be identified for this but it was hypothesised that Leap Motion would begin detecting the user's hand as if it was upside down. This would mean the roll of the hand would be fully rotated 180 degrees causing rotation to occur. Fixing this issue was as simple as remove the hands and replacing them in the Leap Motion's field of vision. This bug occurred fairly infrequently, maybe 30 times throughout the main study. Often it would not occur at all for some users but then multiple times for others which implies there was some underlying action or cause that could set it off. This bug was not observed during the development phase of this project, only during the experimental phase.

3.4 Study Functionality

A series of tasks were implemented that participants would need to carry out within the system (see AppendixA.1). These tasks were not prospective memory tasks and were available to the user, as the aim was to test the usability of the system, not the prospective memory of the participant.

A second dialog box located at the bottom of the screen was also introduced to display the current task. This was so the user would not have to check the full list of tasks in the action menu repetitively to find the current task. The current task would update to the next task upon competition of the current task. An example of this dialog box can be seen in Figures 3.1 and 3.2.

A series of information screens and a logging system were also created and are described in detail in the Studies chapter.

4 Studies

Three studies were conducted involving users testing the system. First, a small pilot study, involving experts in the system, to test out the functionality was conducted. Second was the main study, involving many participants aimed to test the system and compare the modes of navigation that were implemented. Third, a small pilot study involving a single stroke patient to test the final system after any further adaptions had been made. All studies were run at the University of Canterbury in the Erskine building. The results from the main study and the second pilot study are shown in the Results chapter.

4.1 Pilot Study

Originally, a small study was envisioned which would test the created system to identify any flaws. The intention was to implement any recommendations before a main study was conducted to assess the usability of the Leap Motion and the various implemented navigational modes. This was later reassessed and the study was scaled back. Instead, a pilot study was conducted involving three experts in the area, senior members of the ICTG including both project supervisors, who tested the system themselves and made many recommendations. Also, some peers from among the the current honours students tested the system to help identify bugs within the system. They tested all the functionality that was implemented at that point, which included: all three navigational modes, state changing, object interaction, inventory and time checking and the implemented tasks.

Several changes were made based on the observations from the pilot study. Two deficiencies were uncovered in the environment (outside the scope of this project), the agent became temporarily stuck. This was fixed by adding a wall in one instance to close off the area in question and by extending the stairs in the second area. One of the experts found trouble with rotating the roll of their dominant hand (right hand in this case) left, but no trouble rotating the roll right. This problem was solved by instructing the user to rotate the entire arm to achieve the desired hand angle, which involved ensuring the user was not too close to the Leap Motion itself as to have enough room to extend the arm to obtain the extra rotational movement. This instruction was incorporated into the information users received before using the system to prevent the problem from occurring. One of the experts' wristwatch was consistently detected as a hand, but the removal of the wristwatch solved the problem once the source was discovered. Again users were advised in later studies to remove any wristwatches or bracelets in the information screens to prevent this. It was found that the navigation and interaction states were non-intuitive. The first expert found she had to pause and think about each state change and found it irritating to have to approach a door in navigation state, switch to interaction state to open the door, then switch back to the navigation state to move through it. They also found the false positive detections of the state changes frustrating as this caused them to suddenly stop moving when they occurred in the navigation state. As a result, the state system was removed entirely. Instead, essentially the navigation state is always active, and when the user presses the space bar, if an object is currently highlighted, that object is activated; otherwise the action menu is brought up. The subsequent experts found this method much more intuitive and user friendly.

The experts found that having to constantly check the next task via the action menu was frustrating. They also found that they began to attempt completion of the tasks from memory, rather than checking the next task, which caused tasks to be completed out of order when they remembered incorrectly. To combat this, the current task is now displayed at the bottom of the screen in a dialog box and is automatically updated to the next task upon completion of the current task. Also, one of the experts suggested that the current number of hands detected be displayed as images instead of just a single number for more clarity, so this too was implemented. The experts recommended that the maximum speeds for movement and rotation be capped at an upper limit and that the movement speeds generally be reduced, which again, was implemented.

Arm fatigue proved to be less of a problem than the literature predicted. None of the experts found that they had to rest their arms during the test run and mentioned only slight discomfort in their arms.

One of the experts also found that the ability to both move forward/backward and rotate at the same time difficult to manage. Often they would be attempting one of these movements and inadvertently also do the other. So this was implemented as mentioned in the Implementation chapter.

4.2 Main Study

For the main study, 30 participants underwent the study. These participants were primarily selected from students studying at the University of Canterbury. The website Subjects Wanted was particularly useful in the recruiting of these participants [18]. All of the sessions were run on the same computer and run in the same room. To conduct this study, ethics approval was sought for and gained (see Appendix A.4). Each participant also received $20 worth of cafe vouchers for their time.

The study was planned so that each participant would trial each of the three navigational methods twice: a practice run followed immediately an actual run, making six trials in total. The practice run involved eight tasks and was for familiarisation with the current mode while the actual run involved nine tasks and was what the collected data would be from. The sets of tasks were implemented such that all the functionality of the system was tested, so object interaction, crouching, time and inventory checking were all involved in the tasks. It was expected that the tasks would be completed in the order they are given.

There were three navigational modes which meant there were six orders in which they could be done. For instance, airplane metaphor, gas pedal plus airplane metaphor and positional mode represent one possible ordering. It was ensured that each of these orders was tested the same amount of times to compensate for any practice effect that might occur as participants grow more used to the system and familiar with the tasks. With the 30 participants that were recruited, this meant every possible ordering was tested five times.

A series of windows containing information were created for the study that are displayed before the users enter the actual environment. The first screen displays the general information about what they will have to do and how many times they will have to do it. At this screen the user also specifies which hand is their dominant hand. The next screen displays the current navigational mode and describes how navigation and interaction are done in this particular mode. This screen also displays whether the current trial is a practice run or an actual run. The last screen displays the tasks that the user will have to accomplish in this trial. The screens are shown again at the end of each trial, and are updated with the information about the next mode to be used, except for the initial general screen. All of this behaviour was automated so that once the user begins, they would not need further input from the supervisor unless they had a question.

To retrieve data from each trial, a logging system was implemented in which a number of actions are recorded by the environment and written to file (see AppendixA.2). The actions were also logged for each individual task, so data can be examined for individual activities within the environment. The aim was to retrieve meaningful results from this data to compare the three modes of navigation.

A questionnaire was filled in by participants after they had finished the study (see Appendix A.3.1).

4.3 Second Pilot Study

The second pilot study involved a stroke patient testing the system once some revisions had been made after the main study had run. The biggest modification was the removal of the spacebar as mentioned in the Implementation chapter. This study only involved the testing of one of the modes, the positional mode, as this was found to be the highest ranked mode by participants in the main study, as mentioned in the results. The participant completed both the practice and actual task sets for this mode.

5 Results

Each session ran approximately between 20 and 40 minutes. One participant experienced motion sickness while using the system, enough so that by the third mode they felt too sick to continue, so their data was not included for analysis. The participant mentioned that they often succumb to motion sickness while using virtual reality systems and they did not believe this particular system was the cause of their motion sickness, but was just a problem they personally experienced. No other participants reported any feelings of motion sickness.

5.1 Questionnaire Information

The exact questions asked are specified in the Appendix (see Appendix A.3.1).

5.1.1 Demographic Information

The first section of the questionnaire was concerned with demographic questions. The following break down of participants was obtained:

Table 5.1: Questionnaire Demographic Information

	Count	Percentage
Gender		
Male	21	70.00
Female	9	30.00
Age (years)		
18-23	16	53.33
24-29	11	36.67
30-35	1	3.33
36-41	1	3.33
42-47	1	3.33
Computer Game Time Per Week (hours)		
None	7	23.33
0-1	5	16.67
1-5	10	33.33
5-20	6	20.00
20+	2	6.67
Previous Gesture Control Time (hours)		
None	11	36.67
0-1	5	16.67
1-5	5	16.67
5-20	6	20.00
20+	3	10.00

5.1.2 Categorical Data

Next is the information from the subjective categorical data from the questionnaire:

Table 5.2: Questionnaire Categorical Data

	Count	Percentage
Fatigue		
None	2	6.67
Slight	18	60.00
Moderate	6	20.00
Considerable	4	13.33
Extreme	0	0.00
Rank 1st		
Mode 1	9	30.00
Mode 2	4	13.33
Mode 3	17	56.67
Rank 2nd		
Mode 1	15	50.00
Mode 2	5	16.67
Mode 3	10	33.33
Rank 3rd		
Mode 1	6	20.00
Mode 2	21	70.00
Mode 3	3	10.00
Mode Ranking		
123	1	3.33
132	8	26.67
213	2	6.67
231	2	6.67
312	13	43.33
321	4	13.33

In Table 5.2, mode 1 refers to the airplane metaphor navigational mode, mode 2 to the gas pedal plus airplane mode and mode 3 to the positional mode. Rank 1st refers to how many participants rated a particular mode 1st, similar for rank 2nd and rank 3rd. The mode ranking refers to a count of how many participants ranked the modes in particular orders. The in Table 5.2 is categorical, so running a Chi Squared test on each set of data gives:

Table 5.3: Chi Squared test on data from table 5.2

	p-value	Significance
Fatigue	0.00	Significant
Rank 1st	0.01	Significant
Rank 2nd	0.08	Not significant
Rank 3rd	0.00	Significant
Mode Ranking	0.00	Significant

5.1.3 Feedback Questions

All the feedback received on the questionnaire can be found in the Appendix (see Appendices A.3.2, A.3.3, A.3.4 and A.3.5).

5.2 Data Analysis

To retrieve all the data used in this section, the raw data from the sessions was recorded into text files and uploaded in Microsoft Excel. Then filtering was done within Excel and specific data sets which chosen and analysed using IBM Statistical Package for the Social Sciences (SPSS). The practice effect from participants improving as they progress through the modes and become more familiar with the tasks was essentially marginalised out by ensuring each particular order of modes was trialed equally. The two main tests used to analyse the data were the Friedman test and the Kruskal-Wallis test, which are both implemented in SPSS. These are both non-parametric tests which do not assume a normal distribution and can compare multiple samples to predict if they are sampled from the same distribution (the null hypothesis) or different distributions (the alternate hypothesis). All tests were run with a confidence interval of 95%. The Friedman test is used when the sample groups are matched, for instance, when comparing the performance of each mode. The Friedman test is used as the same group, the 30 participants minus the one participant who became ill, tried each mode. The Kruskal-Wallis test is used when the sample group are non matched and independent, for example, when comparing the participants performance based on how much time they play computer games a week as this partitions the participants into separate groups. Once the tests have been run, SPSS provides post-hoc analysis showing different pairwise comparisons to find exactly which comparisons were significant if significance is detected overall. All the data used was from the actual trials and not the practice trials. Justification and explanation of all the tests is saved for the Discussion chapter.

It is first worth looking at the descriptive statistics for the total across all modes for all the actual trials the participants completed:

Table 5.4: Time Taken On Actual Trial For All Navigational Modes

	N	Minimum	Maximum	Mean	Std. Deviation
TotalTime	87	96.47	455.71	197.57	74.32

The first test conducted was comparing the total time it took each participant to complete each mode and comparing across modes with the Friedman test as each participant trialed each of the three modes.

Table 5.5: Navigational Mode vs. Time Taken On Trial

	N	Minimum	Maximum	Mean	Std. Deviation
Mode1	29	96.47	323.41	177.52	55.84
Mode2	29	164.21	455.71	237.84	78.51
Mode3	29	106.42	415.68	177.35	71.88

Table 5.6: Friedman test: Navigational Mode vs. Time Taken On Trial

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Mode1, Mode2 and Mode3 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 5.7: Post-hoc: Navigational Mode vs. Time Taken On Trial

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Mode3-Mode1	.034	.263	.131	.896	1.000
Mode3-Mode2	1.000	.263	3.808	.000	.000
Mode1-Mode2	-.966	.263	-3.677	.000	.001

Now looking at the total time for the first trial undertaken for each participant, and comparing across the three modes. There were 29 participants with nine trialing mode 1 first, ten trialing mode 2 first and ten trialing mode 3 first. Now the data is partitioned into three groups so the Kruskal-Wallis test is used.

Table 5.8: 1st Trial Navigational Mode vs. Time Taken On Trial

	N	Minimum	Maximum	Mean	Std. Deviation
Mode1	9	149.02	323.41	220.57	58.59
Mode2	9	164.21	452.39	257.94	91.41
Mode3	10	132.17	415.68	233.43	94.34

Table 5.9: Kruskal-Wallis test: 1st Trial Navigational Mode vs. Time Taken On Trial

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of TotalTime is the same across categories of Mode.	Independent-Samples Kruskal-Wallis Test	.596	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Now a similar test is conducted: total time for the third trial undertaken for each participant, and comparing across the three modes. Comparison with the second trial across the three modes is left out as the aim is demonstrate a learning effect from the start, trial one, to the end, trial three. There were 29 participants with ten trialing mode 1 first, nine trialing mode 2 first and ten trialing mode 3 first. Again the Kruskal-Wallis test is used.

Table 5.10: 3rd Trial Navigational Mode vs. Time Taken On Trial

	N	Minimum	Maximum	Mean	Std. Deviation
Mode1	10	122.64	252.98	160.84	43.99
Mode2	9	167.82	247.77	202.60	31.35
Mode3	10	106.42	222.48	154.20	35.51

Table 5.11: Kruskal-Wallis test: 3rd Trial Navigational Mode vs. Time Taken On Trial

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of TotalTime is the same across categories of Mode.	Independent-Samples Kruskal-Wallis Test	.015	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 5.12: Post-hoc: 3rd Trial Navigational Mode vs. Time Taken On Trial

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Mode 3-Mode 1	1.100	3.808	.289	.773	1.000
Mode 3-Mode 2	10.378	3.912	2.653	.008	.024
Mode 1-Mode 2	-9.278	3.912	-2.371	.018	.053

Next computer game time per week was compared with total time taken on trial, with the Kruskal-Wallis test.

Table 5.13: Computer Game Time Per Week vs. Time Taken On Trials

	N	Minimum	Maximum	Mean	Std. Deviation
None	21	96.47	455.71	241.19	94.97
0-1	15	113.12	377.12	182.25	64.59
1-5	27	110.99	452.39	197.26	74.08
5-20	18	114.19	264.86	171.98	35.42
20+	6	121.35	231.73	161.33	42.77

Table 5.14: Kruskal-Wallis test: Computer Game Time Per Week vs. Time Taken On Trials

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of TotalTime is the same across categories of ComputerGameTime.	Independent-Samples Kruskal-Wallis Test	.043	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 5.15: Post-hoc: Computer Game Time Per Week vs. Time Taken On Trials

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
20+-5-20	-8.056	11.907	-.677	.499	1.000
20+-0-1	8.567	12.201	.702	.483	1.000
20+-1-5	14.944	11.400	1.311	.190	1.000
20+-None	-27.833	11.692	-2.380	.017	.173
5-20-0-1	.511	8.831	.058	.954	1.000
5-20-1-5	6.889	7.686	.896	.370	1.000
5-20-None	-19.778	8.113	-2.438	.015	.148
0-1-1-5	-6.378	8.134	-.784	.433	1.000
0-1-None	-19.267	8.539	-2.256	.024	.241
1-5-None	-12.889	7.349	-1.754	.079	.795

The previous amount of time the participant had spend using gesture-based devices was compared against the total time, again with the Kruskal-Wallis test.

Table 5.16: Previous Gesture Time vs. Time Taken On Trials

	N	Minimum	Maximum	Mean	Std. Deviation
None	33	96.47	415.68	203.02	77.49
0-1	15	138.64	452.39	199.11	80.06
1-5	12	130.59	264.86	171.84	42.44
5-20	18	110.99	455.71	210.13	90.72
20+	9	121.35	247.77	184.20	50.06

Table 5.17: Kruskal-Wallis test: Previous Gesture Time vs. Time Taken On Trials

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of TotalTime is the same across categories of GestureTime.	Independent-Samples Kruskal-Wallis Test	.781	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Now a comparison between the modes and the time spent rotating conducted is made with the Friedman test, first looking at left rotation. Only the data from participant with right hand as dominant were used for these tests. The same would have been done with the left handed participants, but there were only two, which was not enough to make an analysis.

Table 5.18: Navigational Mode vs. Time Spent Rotating Left

	N	Minimum	Maximum	Mean	Std. Deviation
Mode1	27	13.83	54.35	28.28	10.22
Mode2	27	19.85	104.34	31.73	16.42
Mode3	27	11.04	41.37	21.51	7.03

Table 5.19: Friedman test: Navigational Mode vs. Time Spent Rotating Left

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Mode1, Mode2 and Mode3 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.008	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 5.20: Post-hoc: Navigational Mode vs. Time Spent Rotating Left

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Mode3-Mode1	.667	.272	2.449	.014	.043
Mode3-Mode2	.778	.272	2.858	.004	.013
Mode1-Mode2	-.111	.272	-.408	.683	1.000

Now for right rotation.

Table 5.21: Navigational Mode vs. Time Spent Rotating Right

	N	Minimum	Maximum	Mean	Std. Deviation
Mode1	27	21.00	73.47	36.75	14.30
Mode2	27	21.30	64.98	36.56	11.81
Mode3	27	16.03	50.35	27.12	7.32

Table 5.22: Friedman test: Navigational Mode vs. Time Spent Rotating Right

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of Mode1, Mode2 and Mode3 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.009	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 5.23: Post-hoc: Navigational Mode vs. Time Spent Rotating Right

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Mode3-Mode2	.704	.272	2.586	.010	.029
Mode3-Mode1	.741	.272	2.722	.006	.019
Mode2-Mode1	.037	.272	.136	.892	1.000

Lastly, data from a previous study is included. This data is from a study which used the same system with the same set of tasks to asses two devices: a joystick and another device called the Razer Hydra. The Razer Hydra is 3D positional tracking joystick that is held by the user and can be move freely in space. This previous study was conducted under same conditions as the current study and was held earlier in the same year. Times for trial on these devices are included and compared with times for the trialing of the three modes.

Table 5.24: Navigation Mode, Joystick, Razer Hydra vs. Time Taken On Trial

	N	Minimum	Maximum	Mean	Std. Deviation
Mode1	29	96.47	323.41	177.52	55.84
Mode2	29	164.21	455.71	237.84	78.50
Mode3	29	106.42	415.68	177.35	71.88
Joystick	19	70.85	224.00	129.60	41.61
Hydra	19	100.47	459.25	178.81	85.87

Table 5.25: Kruskal-Wallis test: Navigation Mode, Joystick, Razer Hydra vs. Time Taken On Trial

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of TotalTime is the same across categories of Mode.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 5.26: Post-hoc: Navigation Mode, Joystick, Razer Hydra vs. Time Taken On Trial

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Joystick-Hydra	23.632	11.754	2.011	.044	.444
Joystick-Mode 3	-25.243	10.693	-2.361	.018	.182
Joystick-Mode 1	-28.795	10.693	-2.693	.007	.071
Joystick-Mode 2	-60.243	10.693	-5.634	.000	.000
Hydra-Mode 3	-1.612	10.693	-.151	.880	1.000
Hydra-Mode 1	-5.163	10.693	-.483	.629	1.000
Hydra-Mode 2	-36.612	10.693	-3.424	.001	.006
Mode 3-Mode 1	3.552	9.514	.373	.709	1.000
Mode 3-Mode 2	35.000	9.514	3.679	.000	.002
Mode 1-Mode 2	-31.448	9.514	-3.305	.001	.009

6 Discussion

6.1 Data Analysis Discussion

From Tables 5.2 and 5.3 it can be can seen there was a strong user preference for mode 3, the positional mode, and a strong dislike of mode 2, the gas pedal and airplane metaphor mode (see Appendices A.3.2, A.3.3, A.3.4 and A.3.5). Users seemed to have trouble with co-ordination between the two hands in mode 2. Often, they would move both hands in the same motion to accomplish movement, for instance, tilting both hands forward to move forward instead of just the non dominant hand. They would often have to stop, pause, and think about the exact actions they needed to perform to achieve the desired movement. Many users also mentioned their dislike of the use of the spacebar in the system, especially in mode 2 as it was the only two handed mode. These could all have been factors in the users' dislike of this mode and indicate that this mode is less intuitive and user friendly than the others. Looking at Tables 5.6 and 5.7, the users were also much slower in mode 2 compared to the other two modes, which also implies this mode was less user friendly and intuitive than the others. Interestingly, although the participants gave a strong preference for mode 3 as their favourite, in terms of the comparison in the time, again from Tables 5.6 and 5.7, it can be seen that there is no significant difference between mode 1 and mode 3. So while users liked mode 3 more, they did not perform any better in terms of time in the use of mode 3 compared with mode 1. This could have been due to the fact mode 1 was similar to mode 2 and there was a strong dislike of mode 2 which carried over into mode 1.

Also interesting in the comparison of modes is the comparison with the other devices previously tested, the joystick and the Razer Hydra in Tables 5.25 and 5.26. This shows a significant difference between mode 2 and all the other modes, so mode 2 was significantly slower than not just the other two modes but also the joystick and the Razer Hydra. More interesting is the fact that there was no significant difference between the modes 1 and 3 and the joystick and Razer Hydra individually. This implies that these two gesture-based modes are competitive with these non-gesture-based devices.

Looking at Table 5.9, there is no significant difference in the time it takes to complete the tasks for the first mode the user uses, regardless of what that mode is. But Tables 5.11 and 5.12 show that in the third mode they use, the differences between the modes are clear. There could be several reasons for this. One possibility is that there is a learning curve for using gesture-based modes of interaction, so when a user first starts using a gesture-based mode of interaction, they will be slow regardless of how intuitive and user friendly the mode is. Another more likely reason could be that the users are becoming more used to the set of tasks they carry and are able to carry them out more efficiently once they have practiced them, which would justify the changing of the orders of the modes for each participant to combat the practice effect. This could also imply that a prior run through of the tasks by the participants with a more familiar device, such as a keyboard and mouse, could have helped give the study's data more validity.

Users mentioned the fact they found turning difficult in the two airplane metaphor modes. For instance, if the user holds their right hand close to their body and tries to roll it side to side, they will find they can turn it to the right quite freely and it will be difficult to turn it left, due to the physiology of the human arm. This can be remedied by extending the arm outward from the body and attempting the same action. Mentioning this fact to participants would usually cause them to be able to rotate better during the study if they were having trouble. The data in Tables 5.22, 5.23, 5.19 and 5.20 were to see if in modes 1 and 2, the airplane metaphor modes, if there was more time spent rotating right compared with mode 3, the positional mode and less time spent rotating left. A left rotation versus right rotation comparison could not be directly made as this would assume there was equal left and right rotation required to complete the set of tasks, which was not the case. The point of these tests was instead to see if more turning to the right between the airplane metaphor modes than the positional mode and less when turning to the left. What was found instead was that there was a significant difference in the time spent rotating between the positional mode and the other modes for both left and right. So users would rotate much less in general when using the positional mode, which could a good indicator of its superiority. Unfortunately, this did not reveal any analytical differences between the left and right rotation of the airplane metaphors modes as hoped.

Next looking at the the effect of how much time the participants spend playing computer games versus the time it takes to complete the run through. Tables 5.14 and 5.15 show that there was indeed statistical significance here. But it is between spending no hours per week compared with any hours at all. So if a user spends no hours per week playing computer games, then they will most likely be slower than someone who spends anytime at all playing computer games each week. It seems the additional amount one spends after playing computer games for any time at all has no effect, as can clearly be seen in Table 5.15. The only significant difference was found between participants who do and do not play computer games. For instance, comparing zero to one hours with twenty plus hours reveals no significant change in the time taken. This could be due to the fact that users who play computer games are are quicker to learn a new set of set of controls and because they are more used to navigating in and interacting with a virtual environment. It could be assumed that stroke patients, who are normally elderly, may not have had any significant exposure to computer games and could be slower than the averages this study predicts at become proficient at using the system, although this may not be specifically for gesture-based systems, but any system.

Lastly, looking at Table 5.17, there is no significant difference in having previously used gesture-based devices with the time it takes to complete a run through. This is interesting as coupled with the computer game data it can be seen that having experience with gesture-based controllers does carry over into new gesture-based systems, but having experience with computer games carries over into using a virtual system with gesture-based interaction.

6.2 Questionnaire Feedback and Observation Discussion

The original feedback received from the questionnaire in full can be found in the Appendix (see AppendicesA.3.2, A.3.3, A.3.4 and A.3.5). A quick read through is recommended as there are many interesting thoughts, complaints and compliments brought up by the participants.

Many participants commented on the the spinning bug mentioned in the implementation section, where the agent would suddenly being rotating without the rotation action being given. Although it was certainly irritating it was simple to fix once it occurred and it is hoped that this problem will disappear in future updates of the Leap Motion SDK.

The fact that participants could not make the agent simultaneously move forward/backward and rotate was also mentioned negatively in the feedback as the participant felt this was restricting. This non-simultaneous functionality was implemented after recommendation from the first pilot study, mentioned in the Studies chapter, that this would provide greater control to the user. A simple fix would be to let the user decide what functionality the user wanted by providing a toggle which could allow or disallow simultaneous forward/backward movement and rotation.

Another point mentioned often was the participants dislike of having to use the keyboard in conjunction with gestures. As mentioned in the Implementation chapter, the spacebar was removed after the main study and replaced with a closed fist gesture instead.

Many participants also mentioned that they had trouble rotating in certain directions in the airplane metaphor modes as mentioned in the previous section. Often this was helped by suggesting to the participant to stretch out the arm from the body to allow greater freedom in rotating the hand, but this was not intuitive to many participants.

The largest source of complaint among the participants was the crouching mechanism with many participants find it unrealiable and hard to use. It was designed to be a deliberate motion but users would attempt the action too fast or move their hand so that either it was above the height of detection for the Leap Motion, or too low and covered the sensors of the Leap Motion. The crouching functionality could certainly be tweaked but finding optimal values for the timers and height levels involved in its implementation is a harder task and could involve another study specifically testing this functionality. In general it seemed too restrictive in that false negatives occurred much more often than false positives, that is, user's crouching and uncrouching actions failed more often than crouching and uncrouching occurred unexpectedly. Another option would be to change the approach altogether and find another suitable gesture for crouching and uncrouching.

Many participants mentioned the fact they were surprised at how well the system worked which showed they were initially skeptical about a gesture-based system. Although many mentioned it would be hard to compete with a mouse and keyboard while others thought that with more practice, a gesture-based approach to interaction with the environment would be better in the long term of practice.

In the general comments section, many participants also commented that using the system was an enjoyable experience, which could infer that a similar system of gesture-based interaction could be suitable for computer gaming.

6.3 Second Pilot Study Discussion

This pilot study only involved one participant so not much can be drawn conclusively from it. This is compounded by the fact that stroke patients can have a wide range of lasting symptoms, changing case by case. The particular stroke patient who participated in this pilot study had a stroke within the last two years and is still fully able to function on their own although their movement has been impacted by the stroke. During the session the participant just used the positional mode, completing both the practice and actual task sets. This mode was chosen as it was considered the most user friendly and intuitive by participants of the main study and also appeared superior in the results presented. The choice was made not assess the other modes as to not push them too far. Also, as previously mentioned, the spacebar functionality had been replaced by a hand closing gesture. The participant began very slowly, taking a lot of time to get used to navigation and required a lot of repetitive aural guidance, mostly in the form of them asking questions, to remember and executive the required movements. Due to this length of time the participant also found their arm tired and needed to rest 2 or 3 times during the session. The participant's progress was substantial and by the end of the actual trial they were very capable at interaction and navigation within the environment and at a similar standard to participants in the main study.

The participant was much older than all of the participants of the main study by at least 20 years and does not play computer games. So their single data point for the time it took to complete the actual run through, if comparable with anything, could be compared with the average time it took of the first mode tested of participants who spend no time playing computer games per week. There were only seven data points from the main study that fitted this criteria and produced an average time of 284.18 seconds and the time it took the stroke patient to complete their trial was 447.77 seconds, so a sizable difference of around 2 minutes, 40 seconds. But this should just be used as an indication as without more testing no significant analysation can be done. Overall the result of this pilot study was promising and showed that a stroke patient could competently use the system to interact with the virtual environment.

7 Conclusion

The Intelligent Computer Tutoring Group (ICTG) at the University of Canterbury (UC) have created a 3D virtual environment for stroke rehabilitation, specifically, training prospective memory in a safe and familiar setting. A gesture-based interface via the Leap Motion controller was implemented for navigation and interaction within this environment. This system was then assessed in a series of studies and data and observations retrieved from these studies were analsyed to assess the usability of the system.

It was found that gestures can be used successfully as a method of interaction and navigation with a virtual environment. All the requirements for this particular environment were able to be satisfied with purely gesture-based approach, no external devices or input were required by the end of the project. Users were able to navigate, crouch, interact with objects, check their inventory and check the time. It was found that the Leap Motion device was able to provide a suitable medium for the reading of these gestures and converting that information into data that could be successfully transformed into the desired resulting actions. Although, care had to taken to deal with inaccuracies with the Leap Motion's detection of gestures, and some of the functionality claimed to be provided by the API was unreliable. A bug which caused the agent to spin continuously, until the user removed his hands from the Leap Motion's area of detection, often occurred during the main study and its cause could not be identified, but its occurrence was infrequent. While these problems were issues, they were not significant enough to hinder the overall project.

A study was run which involved participants testing the system including testing three different modes of navigation. In the data that was retrieved from the study and the feedback provided by the users it was found that users performed better with and preferred a positional mode navigation over modes involving the angle of the hand like an airplane to control movement. In particular they found the rotating of the roll of the hand to be an unnatural and awkward movement in the airplane modes. Users did not find the use of an external device, namely, the spacebar on the keyboard, intuitive and user friendly and so its functionality was replaced with a purely gesture-based approach, with the fist gesture taking its place. Participants also found the crouching mechanism of raising and lowering the hand to crouch and uncrouch to be erratic and hard to control.

It was found that the two single handed gesture-based navigational modes compared favourably with the joystick as a means of interaction with the environment. This was also the case with the Razer Hydra, a motion sensing 3d controller, but this device would not be classified as a traditional device. There was no data with which to compare the keyboard and mouse and so it is left to future work to compare gesture-based with interaction with a keyboard and mouse combination in a virtual environment.

That data recovered from the questionnaire that participants filled in after completing the study coupled with the data logged from the system revealed that participants who did not spend any time playing computer games would not be as proficient at using the system as participants which did play computer games. Having previous experience with gesture-based devices did not lead to improved performance within the system. Participants predominantly mentioned experiencing slight fatigue in there arm/arms from using the system, with some considering the fatigue to be considerable but none considering it to be extreme. The study sessions only lasted for 20 to 40 minutes with many breaks, so arm fatigue could become more of an issue with extended use of the system.

7.1 Limitations

The Leap Motion SDK is still being developed, even during the progress of this research changes were made which impacted the end result, such as the ability to detect closed fists. Having a fully finished SDK could have led to a different approach to implementation of some of the gestures and a potentially better end result.

The main study only had 30 participants which is a fairly small number to be drawing results from. This is made worse when comparing subsets of the group against each other, such as by the category of how much time they spend playing computer games per week. A larger number of participants could have led to more convincing results. Also the participants themselves were drawn from a very specific demographic, predominantly university students ranging in age from 18 to 25, which could not a good representation of the general populace and especially those who have undergone a stroke.

Only the three navigational modes were tested against each other. There was no comparison for the other functionality the system provided, such as crouching and object interactions. This means that the choices made in the implementation of this of the functionality could be hard to justify and more testing should be done to test their worthiness.

Also, only three modes of navigation were compared and there is room other to be implemented as well, such as the discrete mode described in the Implementation chapter. And again there was not much non-gesture-based data to compare these against or to use as a control group, other than the data from the previous joystick and Razer Hydra study.

7.2 Future work

A lot of the recorded data from the studies remains un-analysed. This includes data about crouching, object interaction and navigational movements and data at a per task level rather than a per trial level. This data could be analysed to see if further information on the comparison of the modes, potentially on a task by task basis. It could also be analysed in regards to the demographic questionnaire data to see if there are different trends in different demographic groups.

Now that a particular mode of navigation has been identified as being the most the user friendly and intuitive out of those tested, studies could now be conducted that directly compare this mode with other traditional devices, other than the joystick, like the keyboard and mouse or with other gesture-based modes that could be implemented, such as the discrete mode that could not be properly implemented on the Leap Motion.

Some users struggled with some actions, in particular with crouching, while others did not have a problem. A possible solution to this is to first train the system on specific gestures so the system adapts to the users preferences for height and speed of certain actions, instead of having preset static variables for these values. This adaptive approach was investigated in work by Cao and could be applied to this system [19].

More studies could be run that test the system with stroke patients or people who had a traumatic brain injury. In an overview of gesture-based devices for the elderly was discussed by Bedi [20]. The overview mentions that this technology can greatly benefit the elderly when the interface is designed correctly and that other devices such as the Microsoft Kinect are already being used for stroke rehabilitation, although focusing on physical rehabilitation rather than mental rehabilitation. This work could be used to help make adjustments to the system to help make it more suitable for the elderly as this project was primarily concerned with a best case use scenario of the system.

The Leap Motion SDK is still in development and is continually being updated. Future update could give the system more consistency and may provide new and improved methods of implementing some of the functionality.

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A Appendix

A.1 Tasks

Tasks completed by the participants during the studies.

A.1.1 Practice Tasks

- Check the time
- Turn on the TV in the lounge
- Take the coca cola from the fridge in the kitchen
- Check your inventory
- Use the pills (medication) in the bathroom
- Take the frying pan in the kitchen beneath the sink in the cupboard
- Check your inventory
- Check the time

A.1.2 Actual Tasks

- Check the time
- Take the orange dress from the washing line
- Check your inventory
- Place the orange dress inside the washing machine
- Turn on the radio in the front room
- Take the box of JATZ from the bottom of the pantry
- Check your inventory
- Feed the fish outside the front of the house in the lake
- Check the time

A.2 Logging

Data that was logged by the system during the studies.

- time started
- time finished
- time taken
- dominant hand
- total movement forward and backward
- time spent moving forward and backward
- average speed moving forward and backward
- total rotation left and right
- time spent rotating left and right
- average speed of rotation left and right
- number of object interactions
- time spent in object interaction menus
- average time spent in interaction menus
- number of crouches and un-crouches
- total time crouched
- average time per crouch
- total number of checks of time
- inventory and task checks
- total amount of times the action menu accessed
- amount of time spent inactive

A.3 Questionnaire

A.3.1 Questionnaire Form

UNIVERSITY OF CANTERBURY

Questionnaire:

What is your age? (*Please circle*)

18-23 24-29 30-35 36-41 42-47 48+

What is your gender? (*Please circle*)

Female Male

Approximately how much time do you spend playing computer games each week? (*Please circle*)

None 0-1 hour 1-5 hours 5-20 hours 20+ hours

Approximately how much time have you spent using gesture based interaction devices before? (*Please circle*)

None 0-1 hour 1-5 hours 5-20 hours 20+ hours

If you have used gesture based devices before, please list the devices you have used:

____

Please rank the three modes of movement from 1st through to 3rd, with 1st being the mode you found the easiest to use in general:

Airplane metaphor (single hand): __

Airplane metaphor (two handed): __

Positional mode (single hand): __

Did you find any specific movements particularly difficult in any of the modes?

Yes No

If yes, please describe the movement(s):

____

How much physical fatigue did you experience in your arms while interacting with the environment?

None Slight Moderate Considerable Extreme

Please Turn Over

Figure A.1: Questionnaire Page 1

How did you find gesture-based interaction compared with more tradition forms of interaction such as a mouse, keyboard and joystick?

Please comment

____

Did you notice any irregularities or problems with the Leap Motion device? (Such as hands not being recognised or actions not being detected)

Please describe

____

Did you find any of the tasks unclear?

Yes No

If yes, which task(s):

____

Any other comments you would like to make about the equipment or the environment?

(*Please write in the space below*)

Figure A.2: Questionnaire Page 2

A.3.2 Describe Problematic Movements Feedback

Crouching in Airplane metaphor (2h) second buggy/unintuitive and a but random at times.

Selecting options - got used to it eventually

Moving backwards in airplane, single hand

Backwards in Airplane metaphor.

The speed of going/moving forward and backward was too fast for me to control.

In two handed mode the camera would sometimes spin uncontrollably, and sometimes it seemed input from one hand was being read from the other

Uncrouching, going backwards

Crouching in all modes, 2h mode airplane, both hands would attempt to do the same thing sometimes, when rotating especially.

Spacebar in two handed mode

Crouching

Crouching in all modes

Up & down (height), two handed hard to stay still at times

Crouching, Keeping still

moving from crouch to standing. Trying to access keyboard without moving position (especially airplane metaphor 2 handed)

twisting arm to go left/right

Crouching/uncrouching

two handed going from moving to pressing spacebar

Airplane metaphor (single hand) wrist based navigation physically uncomfortable.

Using keyboard while in two-handed mode.

Crouch/stand

stopping

Crouching, turning while moving

anything controlled by my left hand, when I brought it back from the spacebar into the controller's field of view

Crouching

A.3.3 Traditional Devices Comparison Feedback

Arm got sore, It didnt feel natural.

It's cool, but (without some kind of better conditioning) couldn't be done for too long.

More fun although slightly more difficult

Got easy very quickly even though difficult at first (compared to a keyboard/joystick). With the positional mode I felt I had a lot of control compared to keyboard

Basic (Control Schemes) interactions are probably better.

It was interesting. Definitely better than keyboard, but needs practice to be easy to use.

Tricky, I often found myself reaching for keyboard shortcuts when navigating menu

Alright, tradition has more exact, accurate movement

easier even though less control

Was expecting it to be a lot more difficult than it actually was in practice. Harder as there was a separation of rotating view & moving forward. Most similar to joystick as each thumb controls an element of screen movement

Harder, with practice would become easier

More intuitive, but also more uncomfortable with no place to rest hands

Clumsy (Inexperienced)

More difficult

Harder, more strain.

less accurate, possibly due to not being able to rotate and move together

Easier for somethings, mouse/input device better for precision

Interesting - hard to tell the limits at times with the range that it would pick up your hand and the degree of tilt it measures. Got better with practice.

hard at first, but with practice it get better.

prefer mouse & keyboard

limbs fatigue much faster without any tactile Pressure being applied back from the device.

Short interactions like handing an object would be easier using gestures while navigation would be relatively easy using traditional interaction.

Initially a bit difficult but much more intuitive and quick to learn. Much better overall.

I'll keep the mouse.

interesting, more challenging but more fun

One can nit use the gesture-based device for a long time.

felt more intuitive and felt like I had more control (apart from the lack of turning & movement)

More intuitive but not as efficient as mouse + keyboard

1. Unusual, obviously. 2. mouse + keyboard or joystick allow turning while moving; didn't find that here Difficult to turn properly & quickly

A.3.4 Irregularities Feedback

Yes. Many times It did not recognize two hands + couldn't rotate + move at the same time

I had problems having both hands recognised in the sun in 2-hand mode - could be because of 1 hand shadowing the other or something.

Hands not detecting all the time. Probably didn't have my hands high enough

Having my hand flat was interpreted as moving forward rather than staying still. Sometimes start spinning uncontrollably but fixed by taking my hand away and replacing it

Backwards action in airplane mode

When you thumb is not stick to other fingers it doesn't work properly.

Often I had issues returning to standing position when accidentally entering it & in two handed mode there were issues such as the ones mentioned previously

crouching

hands not being recognised (could have been human error)

Hands not being recognized, crouch/stand not being detected, room would spin constantly.

Hands not recognized, player going into continuous spin.

Some trouble with hand recognition and crouch detection

Crouching (requires hand-level recalibration, delay)

In two-handed mode I had to be careful to keep both hands close. In positional mode I kept moving too far away to try and go faster.

Only at the beginning when learning, and with two handed mode - hard to use both hands & work together Occasionally needing to repeat a motion.

2 handed airplane- stops recognising hands and spins until recalibrated

Picking up a Fry pan though a closed cupboard. (also with pantry objects) Still highlighting a task eg feed fish, when camera focus was the other way so couldn't access inventory.

went into uncontrolled spin twice? Couldn't really master the hand rotating movement. Hard to crouch.

no

The 2-handed Airplane was not feeling like it had fluid response (it might be that it takes longer to get used to)

occasionally, the sensor could not recognise overlapping hands and apply correction.

Some movements (e.g. ones requiring angle tilt (forward & back) sometimes not picked up, but probably user error.

hand recognition dropped out Positional. paid of "confusion" in airplane mode like PC was getting multiple instructions & didn't know how to proceed.

few times unable to stop rotating, or not detecting both hands

Sometimes when I wanted to stand still, it moved forward

Yes, sometimes my hands slowly moved down unintentionally and that caused me to crouch

crouching was difficult to detect

a few minor problems, but probably due to user error

Sometimes hands not detected

A.3.5 General Feedback

:)

Try turning airplane mode with forward and back movement of hand + avatar

The user interface was well-designed and developed. To me everything was Perfectly fine.

The doors are difficult to get around. I got stuck in the pantry and the cupboard

- With older people I would think they would fatigue quite easily.

- Possible feel more comfortable standing.

Being able to turn and move forward simultaneously would be nice. The current transition is a bit abrupt.

Add an action key hand gesture.

- 1 handed modes easier.

There need to be a way to remedy the strain on muscles after an extended period of continuous use.

Really fun :)

started to feel slightly dizzy, nauseous with the movements, and watching the screen.

lots of fun

3D navigation using gestures seems slightly uncomfortable but interaction with the environment through gestures appear better than traditional input devices.

See benefits for people with problems with using fingers or wrists perhaps. Not sure how interaction with common PC tasks would be implemented.

It works much better than I thought it would

A.4 Human Ethics Committee Communication

A.4.1 Application Form

UNIVERSITY OF CANTERBURY
HUMAN ETHICS COMMITTEE

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

LOW RISK APPLICATION FORM

(For research proposals which are not considered in full by the University Human Ethics Committee)

FOR STUDENT RESEARCH UP TO AND INCLUDING MASTERS LEVEL

ETHICAL APPROVAL OF LOW RISK RESEARCH INVOLVING HUMAN PARTICIPANTS REVIEWED BY DEPARTMENTS

Please read the important notes appended to this form before completing the sections below

1 RESEARCHER'S NAME: Anthony Winter Bracegirdle

2 NAME OF DEPARTMENT OR SCHOOL: Department of Computer Science and Software Engineering

3 EMAIL ADDRESS: awb52@uclive.ac.nz

4 TITLE OF PROJECT: Investigating the Usability of the Leap Motion Controller: Gesture Based Interaction with a 3D Virtual Environment for Stroke Rehabilitation.

5 PROJECTED START DATE OF PROJECT: 27/01/2014

6 STAFF MEMBER/SUPERVISOR RESPONSIBLE FOR PROJECT: Prof. Tanja Mitrovic

7 NAMES OF OTHER PARTICIPATING STAFF AND STUDENTS: Moffat Mathews

8 STATUS OF RESEARCH: (e.g. class project, thesis) COSC460 Research Project

9 BRIEF DESCRIPTION OF THE PROJECT:
Please give a brief summary (approx. 300 words) of the nature of the proposal in lay language, including the aims/objectives/hypotheses of the project, rationale, participant description, and procedures/methods of the project:

This project is part of a larger on-going Marsden project in Stroke Rehabilitation, which focuses on improving Prospective Memory (PM) in stroke patients. We have developed a Virtual Reality (VR) environment for the rehabilitation of prospective memory after stroke. The environment is of a house with normal household rooms and objects than can be activated or picked up. The objective of this project is to analyse and compare different modes of interacting with the environment using the Leap Motion controller. The Leap Motion is a new gesture-based interaction device. They will complete several tasks in a specific order such as taking items from the pantry or turning on the radio. The participants will then complete a short survey asking them to rate their experiences with the devices. The participants will be members of the faculty, student, friends and family and other persons on campus who would be interested in experiencing the VR equipment. Each session should take no longer than one hour.

10 WHY IS THIS A LOW RISK APPLICATION?
Description should include issues raised in the Low Risk Checklist.
Please give details of any ethical issues which were identified during the consideration of the proposal and the way in which these issues were dealt with or resolved.

This is a low risk application because it does not raise any issue of deception, threat, invasion of privacy, mental, physical or cultural risk or stress, and does not involve keeping personal information of sensitive nature about individuals. All participants will be given an information sheet describing the research project and will give consent for their results to be used for analysis. The participants will be fully aware that they can withdraw themselves or their results from the research at any stage. All the data will be kept in a secure environment and only those listed above allowed access to it.

Figure A.3: Human Ethics Committee Low Risk Application Page 1

2

11 PROVIDE COPIES OF INFORMATION & CONSENT FORMS FOR PARTICIPANTS
These forms should be on University of Canterbury Departmental letterhead. The name of the project, name(s) of researcher(s), contact details of researchers and the supervisor, names of who has access to the data, the length of time the data is to be stored, that participants have the right to withdraw participation and data provided without penalty, and what the data will be used for should all be clearly stated. A statement that the project has been reviewed approved by the appropriate department and the University of Canterbury Human Ethics Committee Low Risk Approval process should also be included.

Low Risk Application Form

Figure A.4: Human Ethics Committee Low Risk Application Page 2

A.4.2 Human Ethics Committee Approval

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2014/26/LR

30 May 2014

Anthony Bracegirdle
Department of Computer Science and Software Engineering
UNIVERSITY OF CANTERBURY

Dear Anthony

Thank you for forwarding your Human Ethics Committee Low Risk application for your research proposal “Investigating the usability of Leap Motion Controller: gesture based interaction with a 3D virtual environment for stroke rehabilitation”.

I am pleased to advise that this application has been reviewed and I confirm support of the Department’s approval for this project.

With best wishes for your project.

Yours sincerely

Lindsey MacDonald
Chair, Human Ethics Committee

University of Canterbury Private Bag 4800, Christchurch 8140, New Zealand. **www.canterbury.ac.nz**

F E S

Figure A.5: Human Ethics Committee Approval

A.5 Study Information Sheet

UC UNIVERSITY OF CANTERBURY

Department of Computer Science and Software Engineering
Telephone: +64 322 305 7298
Email: awb52@uclive.ac.nz
Date: 03-02-2014

Investigating the Usability of the Leap Motion Controller:
Gesture Based Interaction with a 3D Virtual Environment for Stroke Rehabilitation

Information Sheet for Study Participants

This study is conducted by Anthony Bracegirdle, a student at the University of Canterbury undertaking Honours in Computer Science. The purpose of the research is to investigate different methods of interacting with a virtual environment using a device called the Leap Motion. The virtual environment being used for the project is a virtual house containing many standard household objects which can be interacted with. The Leap Motion is a new device for gesture-based interaction.

Your involvement in this project will be to use different modes of interaction to navigate and interact with the virtual environment completing straightforward tasks. You will be asked to go through the environment three times using the Leap Motion each time but with different configurations for navigation and interaction. The particular configuration will be detailed to you before begin each run through. Finally, you will be asked to fill in a quick questionnaire asking you about your experience with the devices.

There is no subsequent action you need to take on completing this study.

You will receive $20 worth of vouchers for Café 101 and Reboot Café for your time for taking part in the study

You may receive a copy of the project results by contacting the researcher at the conclusion of the project.

Participation is voluntary and you have the right to withdraw at any stage without penalty. If you withdraw, I will remove information relating to you. This will become impossible once the data has been analysed and results collated.

The results of the project may be published, but you may be assured of the complete confidentiality of data gathered in the investigation: your identity will not be made public without your prior consent. To ensure anonymity and confidentiality, your name and details will not be stored with the data gathered from the study. The only people who will have access to the data will be members of the Intelligent Computer Tutoring Group (ICTG), who are a small group of staff from the Department of Computer Science and Software Engineering.

Figure A.6: Study Information Sheet Page 1

The project is being carried out as part of COSC460 Research Project course at the University of Canterbury by Anthony Bracegirdle under the supervision of Prof Tanja Mitrovic and Dr. Moffat Mathews, who can be contacted at tanja.mitrovic@canterbury.ac.nz and moffat.mathews@canterbury.ac.nz respectively. They will be pleased to discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Human Ethics Committee, and participants should address any complaints to The Chair, Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (Human-ethics@canterbury.ac.nz).

If you agree to participate in the study, you are asked to complete the consent form and return it to Anthony Bracegirdle upon undertaking the study.

Anthony Bracegirdle

Figure A.7: Study Information Sheet Page 2

A.6 Study Consent Form

Department of Computer Science and Software Engineering
Telephone: +64 322 305 7298
Email: awb52@uclive.ac.nz
Date: 03-02-2014

UNIVERSITY OF CANTERBURY

Investigating the Usability of the Leap Motion Controller:
Gesture Based Interaction with a 3D Virtual Environment for Stroke Rehabilitation

Consent Form for Study Participants

I have been given a full explanation of this project and have had the opportunity to ask questions.

I understand what is required of me if I agree to take part in the research.

I understand that participation is voluntary and I may withdraw at any time without penalty. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable.

I understand that any information or opinions I provide will be kept confidential to the researcher and that any published or reported results will not identify the participants.

I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be kept indefinitely in secure electronic form.

I understand the risks associated with taking part and how they will be managed.

I understand that I am able to receive a report on the findings of the study by contacting the researcher at the conclusion of the project.

I understand that I can contact the researcher Anthony Bracegirdle (awb52@uclive.ac.nz) or supervisors Prof Tanja Mitrovic (tanja.mitrovic@canterbury.ac.nz) and Dr Moffat Mathews (moffat.mathews@canterbury.ac.nz) for further information. If I have any complaints, I can contact the Chair of the University of Canterbury Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)

By signing below, I agree to participate in this research project and I have received $20 worth of café gift vouchers.

Name: ______________________________

Signed: ______________________________

Date: ______________________________

Please return this form to Anthony Bracegirdle upon undertaking the study.

Anthony Bracegirdle

Figure A.8: Study Consent Form