



**University
of Manitoba**
Price Faculty of Engineering

An Assistive Smart Mirror for Daily Living

DEPARTMENT OF BIOSYSTEMS ENGINEERING

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Executive Summary

Individuals with mild cognitive impairment (MCI) experience challenges completing hygienic tasks independently due to short-term memory loss and difficulties sequencing tasks together. A caregiver can help by providing reminders and cueing. However, dependency on a caretaker decreases independence which may impact self-confidence.

This smart bathroom mirror, shown in Figure 1, may help individuals with MCI to complete hygienic tasks, supporting independent living. The focus tasks are brushing teeth, flossing teeth, washing face, washing hands, applying deodorant, and brushing hair. The smart mirror reminds the users of their daily hygiene tasks and will proceed with step-by-step cueing when the user activates a task using the keypad.



Figure 1. Home display of the smart mirror

The smart mirror incorporates a custom-built hardwood frame containing a panel of smart mirror glass and a Dell 27" 2722 monitor. A PIR motion sensor, a 9-button keypad, and a Raspberry Pi 3 B+ connect to the monitor. The material of the back panel is Medium Density Fibreboard (MDF) which is secured using screws, allowing access to the internal electronics when needed. Brackets with screws fasten the smart mirror to the wall. The languages used to program the smart mirror are HTML, CSS, and JavaScript.

There were eight tests; of particular interest are the internal heat and humidity tests that ensure the smart mirror's internal temperature remains below 40 °C and relative humidity (RH) does not exceed 30%. The design team also tested the functionality of the smart mirror to confirm that smart mirror technology could effectively cue hygiene tasks.

The main recommendation is for testing to occur with individuals who live with MCI to conclude the effectiveness of a smart mirror in increasing the independence of this population. In addition, recommendations to improve the physical build and software are made.

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1.0 Introduction

1.1.0 Purpose

Individuals with mild cognitive impairment (MCI) struggle to independently complete daily hygienic tasks due to poor executive functioning, forgetfulness, and recall difficulties. Namely, the individuals forget to do a task or forget how to perform a task. This project aims to design a device that guides individuals through hygienic tasks, which may increase the independence of people with MCI.

1.2.0 Background

In Canada, around 747,000 people live with cognitive impairment (Chang et al., 2015). Cognitive impairment is an umbrella term indicating an alteration of the brain's function. No single cause for cognitive impairment exists, as the severity ranges from mild to severe, each requiring different treatments (Ragman et al. 2019).

The severity of cognitive impairment may be defined using the Montreal Cognitive Assessment (MoCA) scale. The MoCA assigns a score between 0 to 30 based on the assessment of written and verbal tests (Jaywant et al., 2020). The average score for someone who does not experience a cognitive impairment is around 27.2, whereas a person with MCI scores between 18 and 25 (Collier 2020). The MoCA examines eight cognitive functions: executive functioning, immediate and short-term recall, visual perception, fluency, attention, calculation, abstraction, and orientation (MoCA 2022). Furthermore, the MoCA is not an assessment of intelligence but cognitive impairment. Therefore, a low score does not infer that an individual has a low IQ; it implies that they have trouble perceiving, understanding, and remembering things (Collier 2020).

Individuals with MCI experience impairments in their memory, judgment, thinking, and language (Mayo Foundation 2022). There are two classifications of MCI: Amnesic MCI and non-amnesic MCI. Amnesic MCI hinders memory, and non-amnesic MCI hinders a person's thinking, like awareness of time and sequencing steps together to accomplish a significant task (Mayo Foundation 2022). As a result, hygiene routines are challenging to accomplish.

1.2.1 Existing Smart Mirror Technology

A smart mirror is a two-way mirror that simultaneously reflects the objects before the mirror while showing the internal visual display (Jasinski & Hajek 2016). Smart mirrors are commonly designed for and used in the beauty and fitness industries. In addition, do-it-yourself projects allow the creator to multitask by staying informed on specific information while completing their daily routines (Jasinski & Hajek 2016). Figure 2 shows an example of the typical beauty smart mirror.

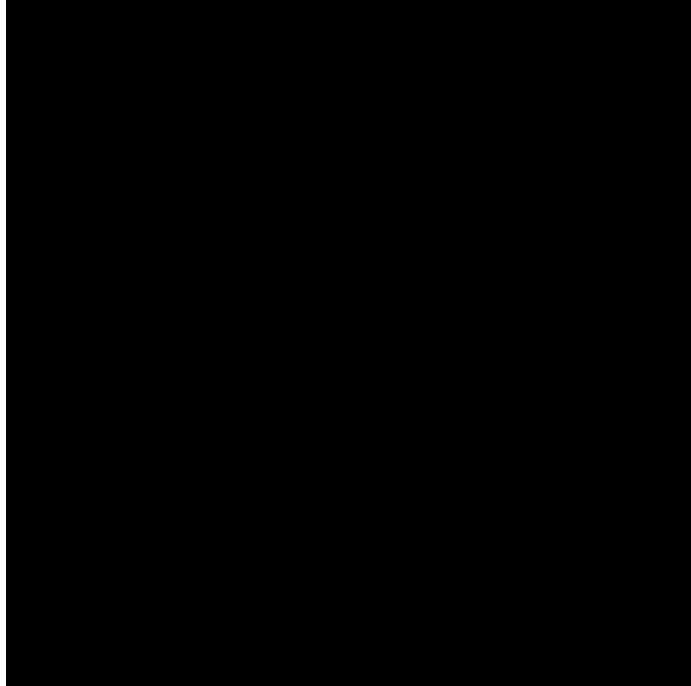


Figure 2. Example of a bathroom smart mirror (Amazon, 2023)

Fitness smart mirrors, for example, developed by Lululemon in Figure 3, allow people to bring state-of-the-art gyms into their homes (Lululemon 2022). The typical function of these mirrors is to provide an on-screen workout, either live or recorded, with the live workouts adding feedback and personal encouragement from a trainer (Lululemon 2022). These smart mirrors cost between \$1000-\$3000 (Gallagher 2022).

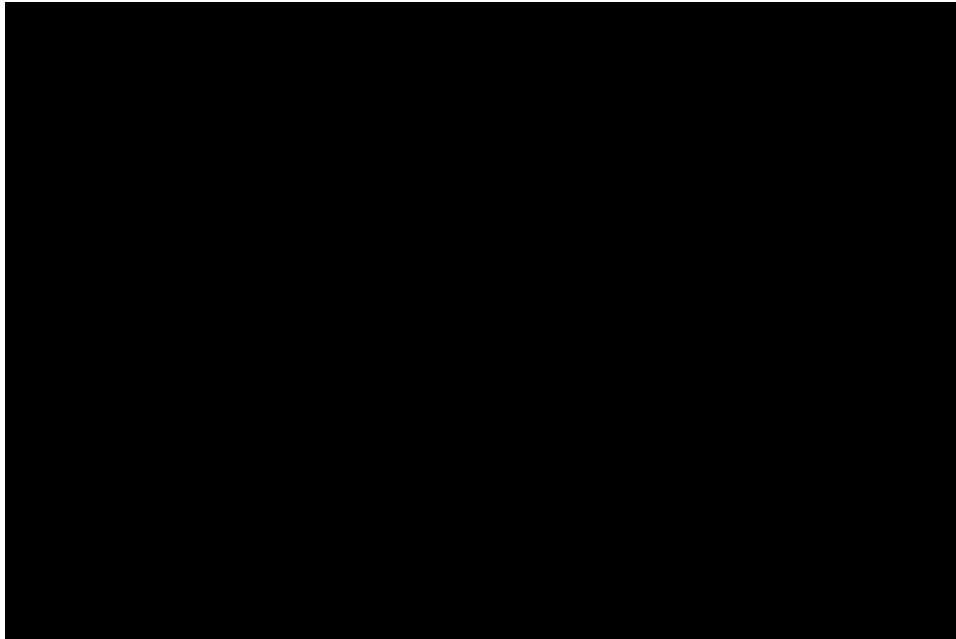


Figure 3. The Lululemon fitness smart mirror (InsideHook, 2021)

1.2.2 Building a Smart Mirror

Before building a smart mirror, choose the desired functions, as these decisions influence design decisions like size and processing. Smart mirrors are highly customizable based on the creator's needs and expertise. However, the general function is for the smart mirror to display widgets of information for the user to read (Jasinski & Hajek 2016).

Next, select a two-way reflective material. Though glass is more robust and scratch-resistant than acrylic, it is also more expensive, heavier, and fragile. In addition, select material for the frame box to enclose the electrical components. This material must be water-resistant and capable of dispersing some of the internal heat created by the electrical components. Finally, select the hardware and software. Figure 4 shows the typical components of a smart mirror.

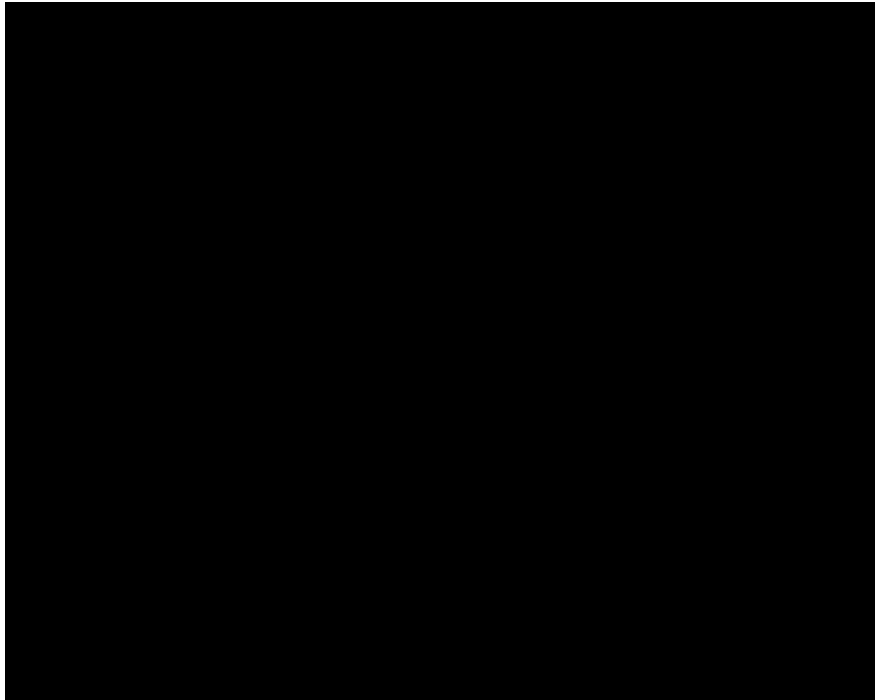


Figure 4. Components Required in the Typical Smart Mirror (Glancer, 2023)

1.2.3 Display Characteristics

The display of a smart mirror commonly uses text to convey critical information; therefore, the background color, font type, and text colors are essential. According to Aleman et al. (2018), white text on a black background (or vice versa) is not ideal, as extreme contrast can increase eye strain. However, a smart mirror requires a dark background to provide adequate reflection. Conversely, most smart mirrors use a white font, so the choice of color occurs through testing.

Accessibility and Usability at Penn State recommend the font Verdana. However, Verdana might be problematic as the letter "a" has an overhang, which is not standard. Again, testing is necessary to determine if Verdana is the optimum font choice.

1.2.4 Passive Infrared Sensors

A Passive Infrared (PIR) motion sensor, shown in Figure 5, detects motion through infrared technology and creates a positive or negative differential charge (Ada, 2022).

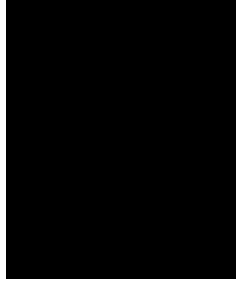


Figure 5. A Passive infrared motion sensor

A PIR motion sensor has two sensors; when a person walks by, a positive differential between the two sensors occurs. When the person leaves, there is a negative differential between the two. The PIR motion sensors are in a case to prevent humidity, noise, and temperature from influencing the measurements.

1.3.0 Problem Definition

Individuals with MCI have poor executive functioning; therefore, they tend to forget the steps of basic hygiene tasks or forget the task altogether (Mayo Clinic 2020). This forgetfulness causes inconvenience and frustration in their daily life, decreasing their confidence. The belief is that a smart mirror may assist people with MCI and allow them to regain independence. A smart mirror displays different types of information on top of providing a reflective surface (Illinois Institute of Technology 2016). In this case, a smart mirror will remind users to complete specific personal hygiene tasks and cue each of the task's steps. The smart mirror will be placed in the Smart Suite at Rehabilitation Sciences, over the sink, with expected users being individuals with MCI and clinicians as they continue to interact with and test the product.

1.3.1 Problem Statement

Individuals living with MCI experience challenges from short-term memory loss and difficulties sequencing tasks together. The hypothesis is that a smart mirror can guide users in the washroom by cueing hygienic tasks. Thus, reducing the individual's dependency on a caregiver. A smart mirror prototype must be developed before this hypothesis can be proven.

1.3.2 Functions, Objectives, and Constraints

The smart mirror's functions, associated objectives, and constraints are in Table 1.

Table 1 - Smart Mirror Functions, Objectives, and Constraints

Function (requirement)	Objective	Constraint
The visual display does not obstruct the user's reflection	n/a	When the user is 2 ft in front of the mirror, the smart mirror's visuals do not obstruct their face
The smart mirror's display provides clear visual feedback	n/a	100% of the visual display's text can be read clearly by the user with 20/20 vision standing 2 ft from the mirror
Accurate keypad function	n/a	The activated key initiates the correct function 100% of the time

Function (requirement)	Objective	Constraint
The keypad does not delay the user	The activated key initiates a function in < 1 second	The activated key initiates a function in < 5 seconds
The smart mirror is awake while the user is in front of the mirror	The smart mirror awakes when the user	The smart mirror is awake while the user in front of the mirror
The temperature inside the smart mirror is < 40°C	n/a	The temperature inside the mirror remains < 40°C
The relative humidity (RH) inside the smart mirror is < 30%	n/a	RH inside the mirror remains < 30%
Priced comparable to other smart mirrors	Costs ≤ \$1200 CAD	Costs ≤ \$2000 CAD

1.4.0 Scope of the Project

As determined by the clients, the smart mirror's project scope has four primary components:

1. The stakeholders believe that individuals with MCI (18-25 MoCA) may benefit from this smart mirror. Individuals above 25 do not require assistance, and the mirror would be too complex for those below 18.
2. No testing occurs with individuals with MCI, as requested by the clients. The project's testing focuses on the overall capability of the mirror to provide cueing for hygienic tasks.
3. The smart mirror is a prototype for proof-of-concept. As such, the choice of material and manufacturing techniques reflect this, and additional development will be required.
4. The smart mirror has one location of use: the Smart Suite at Rehabilitation Sciences College.

2.0 Smart Mirror Design

The building process is in Appendix D, and Figure 6 shows the fully assembled smart mirror. The smart mirror design comprises five sections: (1) physical build, (2) component parts, (3) inputs and outputs, (4) software, and (5) user interaction. The following describes each in further detail.



Figure 6. Fully assembled smart mirror

2.1.0 Physical Build

There are five main components to the physical build: (1) Frame, (2) holes for ventilation and wiring, (3) glass and electrical component supports, (4) backboard, and (5) frame supports. The design of each component was chosen through research and consultation with professional engineers who gave feedback on three design areas: structural integrity, ventilation, and water resistance. The physical build is shown in Figure 7, with the following sub-sections further explaining the details.

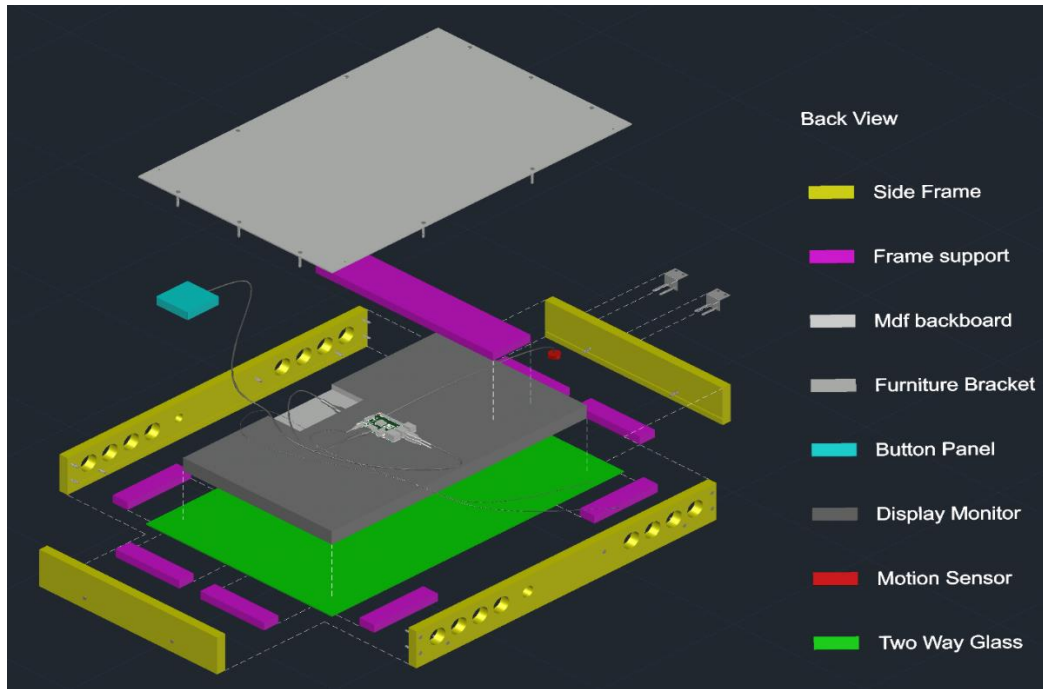


Figure 7. Exploded rear view of the smart mirror build

2.1.1 Frame

The frame is the main structure of the smart mirror, containing the electrical components and protecting them from the bathroom's humid environment. The frame also secures the glass and monitor in place. The dimensions of the frame are shown in Figure 8.

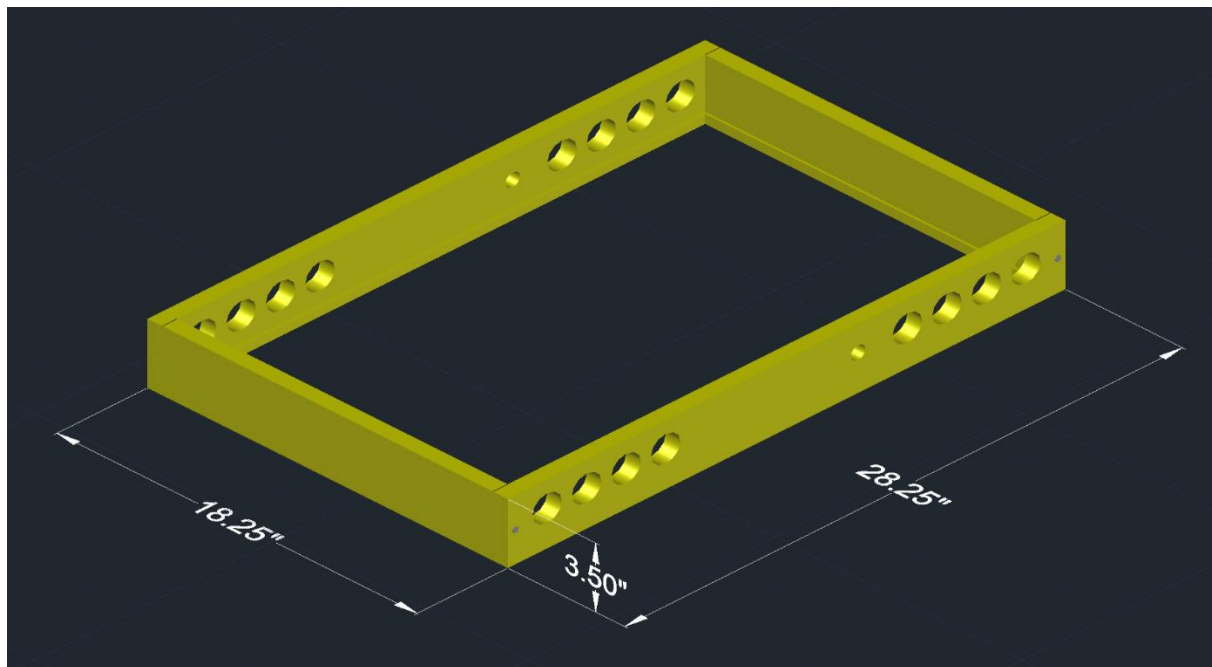


Figure 8. Dimensions of the smart mirror frame

2.1.2 Holes for Ventilation and Wiring

The frame has eight ventilation holes per side, 1 ½" in diameter, and spaced 2" apart, as demonstrated in Figure 9.



Figure 9. Dimensions for ventilation and wiring holes

Hydrophobic mesh covers the holes to protect the internal components of the mirror. The mesh is a smooth polyester plastic monofilament with a hydrophobic coating; water droplets and vapor can not pass through the mesh. Since it is a woven fabric, there are small gaps where the air can move through to remove hot air and allow cold air to enter. The frame also has two ¾" diameter holes on either side.

2.1.3 Glass and Electrical Component Supports

The frame's groove, shown in Figure 10, secures the smart mirror glass (green).

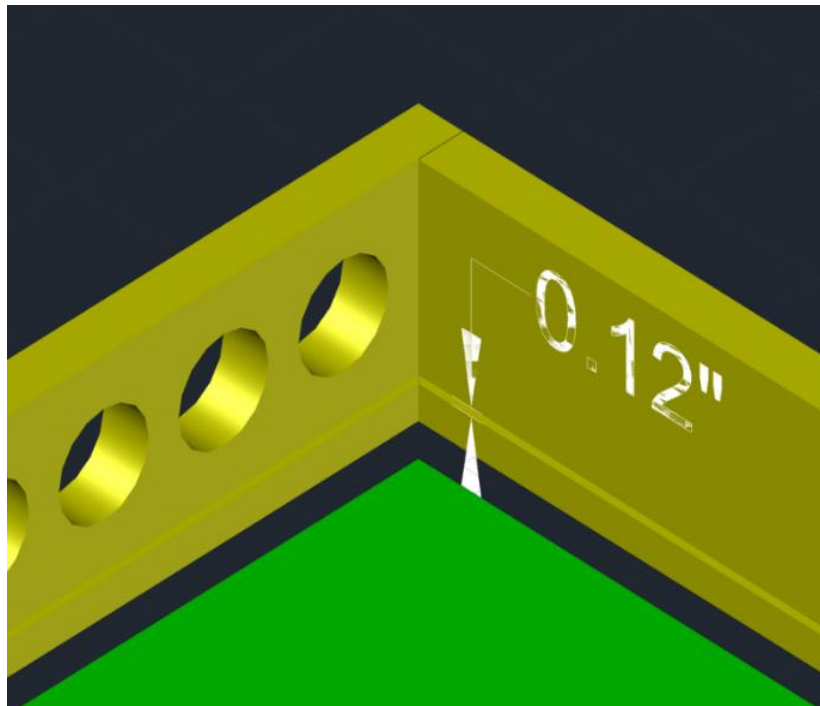


Figure 10. Smart mirror glass secured by a groove

Five supports (pink), shown in Figure 11, secure the monitor directly behind the glass.

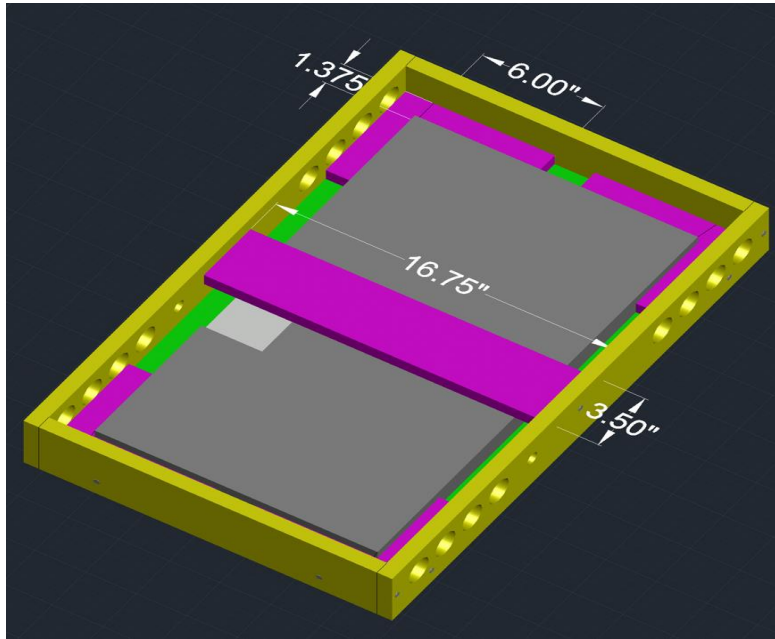


Figure 11. Supports used to secure the monitor

In the center point of each wood piece is a #8, 1 ½" stainless steel screw to secure the four corner supports. These pieces create a tight fit for the monitor, preventing tipping in the horizontal and vertical planes. Two #8 1 ½" self-tapped screws secure the middle support.

Figure 12 shows the mechanism to secure the Raspberry Pi. The groove on the back of the monitor, used to prop the monitor on a stand, creates a tight fit for the Raspberry Pi.



Figure 12. Raspberry Pi secured in the back of the monitor

2.1.4 Backboard

The backboard in Figure 13 is made from an MDF panel to seal the inner components and protect them from moisture.

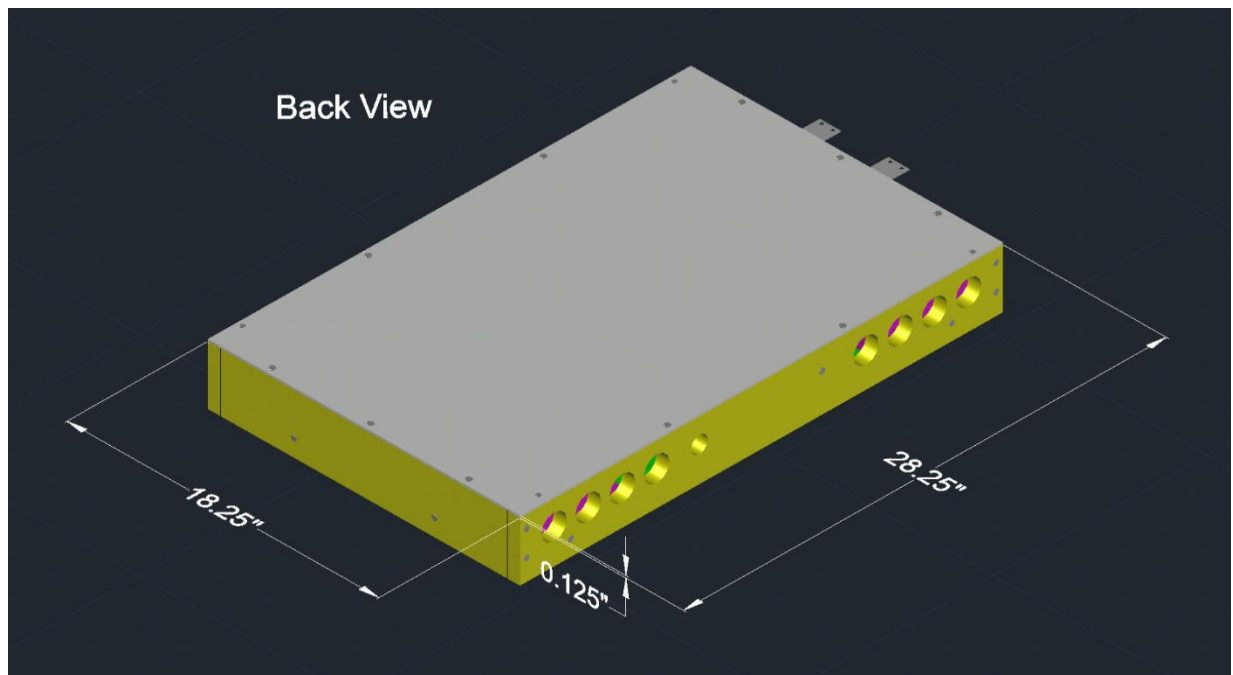


Figure 13. The mirror backboard

2.1.5 Frame Supports

In this project's scope, there is one location for the smart mirror: the bathroom of the Smart Suite located at the Health Sciences Center. This bathroom has a ledge that the smart mirror sits on to support the mirror's weight. Two furniture brackets (Figure 14) secure the mirror to the wall to prevent the mirror from tipping forward.

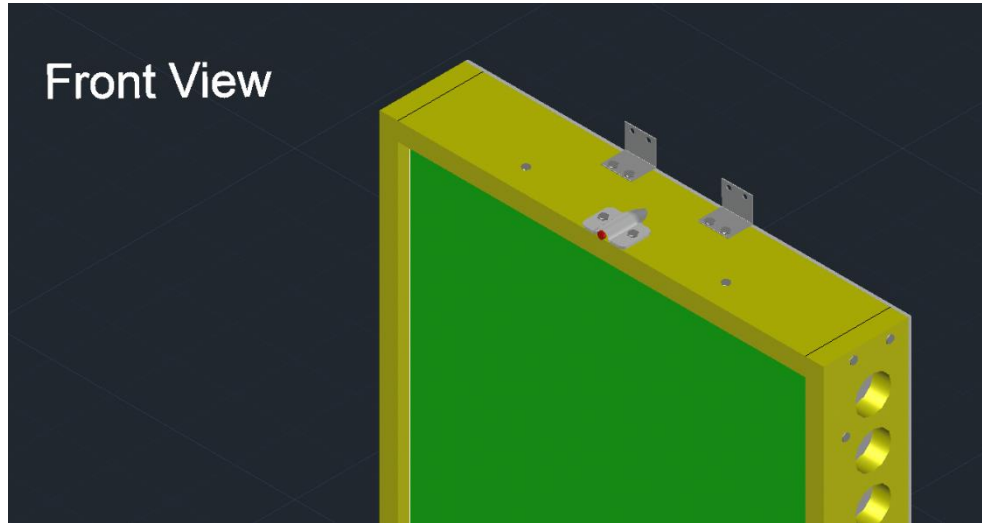


Figure 14. Furniture brackets used to secure the mirror to a wall

2.2.0 Component Parts

A decision matrix (Appendix C) was used for this project to choose the 6 component parts. Table 2 contains an overview of these components.

Table 2 - Overview of Chosen Building Materials and Electrical Components

Building Material or Electrical Component	Choice of Item
Visual display	27" Dell 2722 monitor
Microcontroller	Raspberry Pi 3 B+
Motion sensor	PIR motion sensor
User interface	Insignia keypad
Building material	Pinewood
2-way reflective material	Smart mirror glass (Two-way Mirrors, 2023)

2.2.1 Insignia Keypad

The insignia keypad has 19 keys, but the smart mirror only requires nine. The function of each key is in Table 3.

Table 3 - Function for Each Key

Key Name	Key Function
Back	Move backward in the current task's steps
Forward	Move forward in the current task's steps
Exit	Cancel task
Wash Hands	Wash hands task
Deodorant	Apply deodorant task
Brush Hair	Brush hair task
Brush Teeth	Brush teeth task
Floss Teeth	Floss teeth task
Wash Face	Wash face task

For this project, the keypad has two design changes. First, to reduce distraction, a 3D-printed cover hides the unused keys. Second, icon stickers identify each key's function to enhance ease of use. These design modifications are in Figure 15.



Figure 15. Modified Insignia keypad with 3D-printed cover and icons representing the tasks described in Table 3

2.2.2 Electrical Schematic

For this project, there are four electrical components: (1) Raspberry Pi 3 B+, (2) PIR motion sensor, (3) Dell 2722 monitor, and (4) Insignia keypad. The electrical circuit connects to the power source in the bathroom wall using the power cords for the monitor and Raspberry Pi. Figure 16 shows that the keypad connects to the Pi's USB port and the motion sensor to the Pi's connection pins.

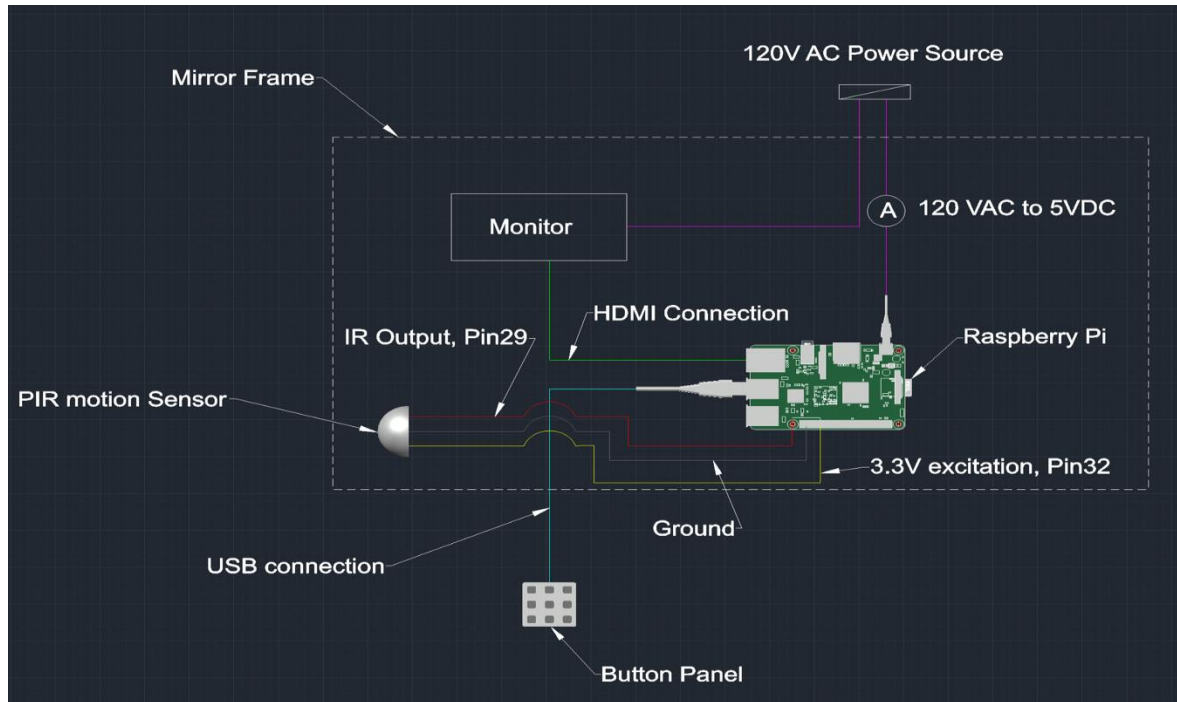


Figure 16. Electrical schematic of the smart mirror components

2.3.0 Inputs and Outputs

There are four inputs to the smart mirror, and one output, summarized in Table 4.

Table 4 - Inputs and Output of the Smart Mirror

Inputs	Wireless Internet, motion sensor, keypad, 120V AC, 60 Hz
Outputs	Reflective visual display
Functionality	Informational widgets on the display The user can interact with the mirror using the keypad The mirror provides cueing in the form of a written display based on input received from the keypad (user-generated) The mirror powers on when the PIR motion sensor detects motion and enters sleep mode in the absence of motion

The visual display has two parts: the home screen and the task screen. A summary of each screen is in Table 5.

Table 5 - Information Displayed on the Home and Task Screen

Home Screen Displayed Information	Task Screen Displayed Information
Date and time	Date and time
Task list with checkboxes	Current task
Number of times each task was completed	Current directive to achieve the task
	Progress bar

The visual display design in Figure 17 required consultations with occupational therapists who assisted in determining the ideal layout for the displayed information. The occupational therapists also helped write the step list for each task in Appendix F.

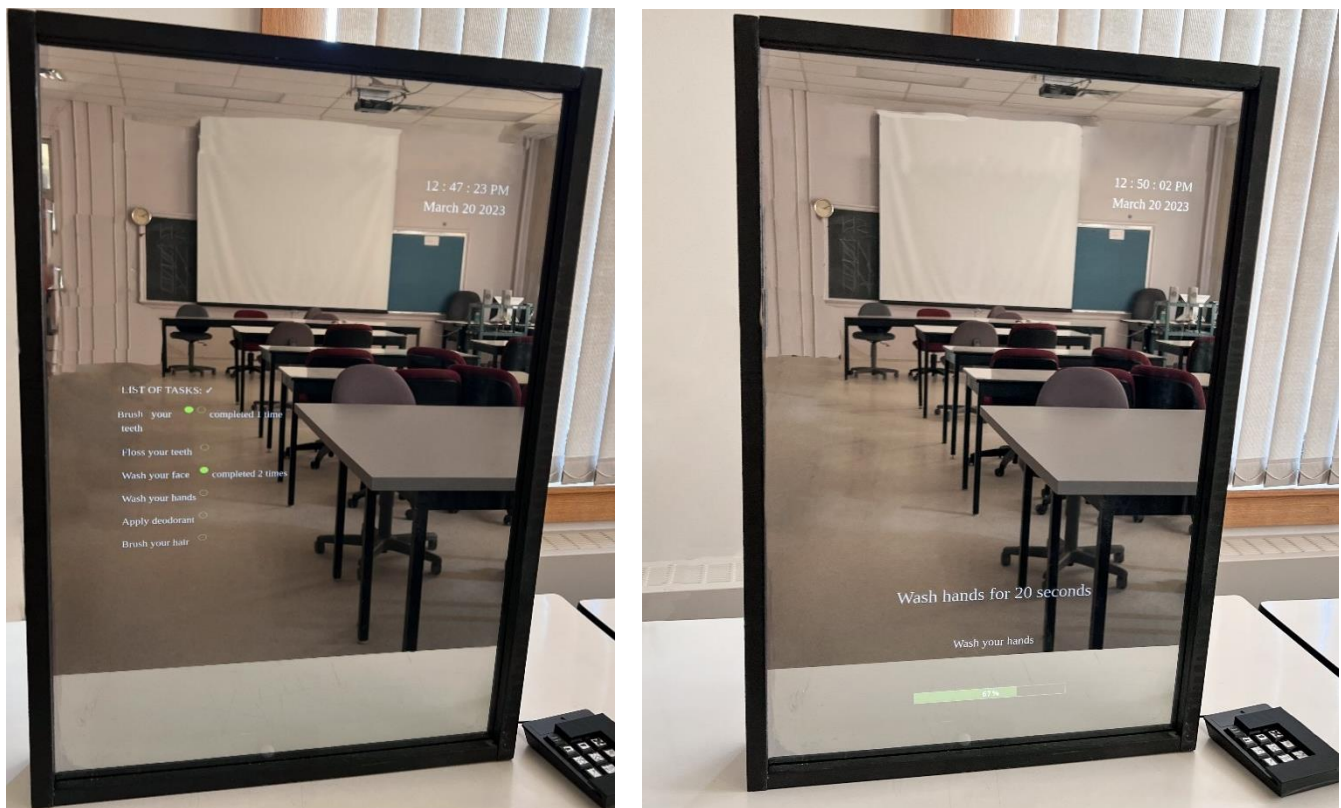


Figure 17. The smart mirror has two displays: (A) the home screen, and (B) the task screen

2.4.0 Software

The visual display is a web form requiring HTML, JavaScript, and CSS for coding. HTML codes the web form's layout, CSS styles the web form, and JavaScript provides functionality. The HTML file creates a placeholder for each information widget displayed on the home and task screens using div blocks with unique id names: clock, taskList, taskStep, taskName, and progressBar. The CSS file styles the widgets by choosing font family, size, and colors and specifies the position for each widget.

The JavaScript file contains 16 functions, which Appendix E summarizes. Each function changes the information that the monitor displays. There is also one function to count how many times a user starts a task each day and one function to record the progress of each task attempt. These two counters are accessible within the web page's console but not on the visual display.

2.5.0 User Interactions

The user indirectly interacts with the smart mirror using the PIR motions sensor and directly using the keypad. If the sensor has not detected motion for 12 minutes, the monitor enters sleep mode. When the sensor detects motion again, the monitor wakes. On the keypad, nine keys allow the user to select a task, move forward and backward through the corresponding steps, and cancel a task. The following steps are examples of how the keys function, with a flow diagram in Appendix E. In this example, if the user pushes **Brush Teeth** to activate the brushing teeth task, the following occurs:

1. The smart mirror displays the home screen
 - the six **Task** keys are active, but **Back**, **Forward**, and **Exit** are not
2. The user pushes **Brush Teeth**
 - The corresponding task name displays on the screen ("Brush your teeth")
 - The 6 **Task** keys are not active
 - **Back**, **Forward**, and **Exit** are active
3. The user presses **Forward** to advance through the steps and **Back** to return to the previous step
4. Once the user finishes the steps, the task is complete, and the mirror will return to the home screen
 - Alternatively, if the user presses **Exit**, the mirror will return to the home screen

2.6.0 Summary

In summary, a smart mirror has been developed for use in the bathroom of the Smart Suite at the Health Sciences Center. The user display is contained within a custom-built wooden frame and created using a two-way mirror, supporting monitor, and Raspberry Pi. The user interface is a 9-button keypad and motion sensor. The coding of a web form offers customizable functionality and the ability for user interactions.

3.0 Verification

In total, there are nine tests and one clinician review. Eight tests are requirement tests to ensure that the smart mirror achieves each function, and the other test is to determine the ideal two-way reflective material. Due to time constraints, project testing focuses on the materials and function of the smart mirror. Table 6 summarizes the project requirements, associated testing procedure, pass/fail criteria and the response to failure. The clinician review with four occupational therapists evaluates the smart mirror's overall function, aesthetic, and ease of use.

Table 6 - Testing Methodology, Summary, and Results

Test Name	Project Functions (Requirements)	Testing Procedure	Pass/Fail Criteria		Response to Failure	Result
			Pass	Fail		
Reflection Clarity	The visual display does not obstruct the user's reflection	Procedure 1	When the user is 2 ft in front of the mirror, the smart mirror's visuals do not obstruct their face	When the user is 2 ft in front of the mirror, the smart mirror's visuals obstruct the user's face (in part or full)	Rearrange the layout of the smart mirror's display	Pass
Visual Display	The smart mirror's display provides clear visual feedback	Procedure 2	100% of the visual display's text can be read clearly by the user with 20/20 vision, standing two feet from the mirror	< 100% of the visual display's text can be read clearly by the user with 20/20 vision, standing two feet from the mirror	Increase the text size	Pass
					Change the font	
					Change the text color	
					Darken the smart mirror's display's background color	
					Change the 2-way reflective material	
Keypad Accuracy	Accurate keypad function	Procedure 3	The activated key initiates the correct function 100% of the time	The activated key does not initiate a function	Re-write the code to fix the malfunctioning pathway	Pass
				The activated key initiates a function when it is not supposed to		
				The activated key initiates the incorrect function		

Test Name	Project Functions (Requirements)	Testing Procedure	Pass/Fail Criteria		Response to Failure	Result
			Pass	Fail		
Keypad Response	The keypad does not delay the user	Procedure 4	The activated key initiates a function in < 1 sec	The activated key initiates a function in > 5 sec	Change the delay in the code	Pass
Motion Sensor	The smart mirror is awake while the user is in front of the mirror	Procedure 5	The smart mirror is awake whenever the user is in front of the mirror	The smart mirror sleeps while the user is in front of the mirror	Change the location of the motion sensor	Pass
				The smart mirror does not wake when the user is in front of the mirror	Upgrade the motion sensor	
					Increase the motion sensor's sensitivity	
Temperature	The temperature inside the smart mirror is < 40°C	Procedure 6	The temperature inside the smart mirror remains < 40°C	The temperature inside the smart mirror is $\geq 40^{\circ}\text{C}$	Change the frame material to one with a higher thermal conductivity	Pass
					Increase the ventilation size	
					Add fans inside the smart mirror	
Relative Humidity	The relative humidity inside the smart mirror is < 30%	Procedure 6	The relative humidity inside the smart mirror remains < 30%	The relative humidity level inside the smart mirror is $\geq 30\%$	Waterproof the electrical components with a case or rubberized sealant	Pass
					Select a higher-quality sealant for the smart mirror exterior	
Cost	Cost to build $\leq$ \$2000 CAD	The bill of materials was summed prior to purchasing the supplies	Cost to build $\leq$ \$2000 CAD	Cost to build > \$2000 CAD	Substitute materials for cheaper alternatives that do not compromise the requirements	Pass

2.2.3 Procedure 1: Reflection Clarity Test

This test ensures the visual display does not obstruct the user's reflection. To perform this test, each of the four participants stands (trial 1), sits (trial 2), and kneels (trial 3) two feet in front of the smart mirror, shown in Figure 18. The range of heights is from 4 ft to 6 ft.



Figure 18. Testing the visual display to ensure that the participants face is not blocked by any of the text on the smart mirror: 1. participant standing, 2. sitting, 3. and kneeling

During each trial, the participants record various observations about their reflections. The pass criteria for this requirement is that the smart mirror's visuals do not obstruct the user's face, and the participants can see the entirety of their face.

After conducting this test, the pass criteria was met, and the requirement was satisfied. Table 7 summarizes the test results.

Table 7 - Results of the Reflection Clarity Test

Trial	Height	Can you see your eyes?	Can you see your hair?	Can you see your mouth?	Can you see your nose?
Participant One					
Standing	5'10"	yes	yes	yes	yes
Sitting	4'5"	yes	yes	yes	yes
Kneeling	4'3"	yes	yes	yes	yes
Participant Two					
Standing	5'5"	yes	yes	yes	yes
Sitting	4'2"	yes	yes	yes	yes
Kneeling	3'11"	yes	yes	yes	yes
Participant Three					
Standing	5'11"	yes	yes	yes	yes
Sitting	4'6"	yes	yes	yes	yes
Kneeling	4'2"	yes	yes	yes	yes
Participant Four					
Standing	5'4"	yes	yes	yes	yes
Sitting	4'3"	yes	yes	yes	yes
Kneeling	4'	yes	yes	yes	yes

3.2.0 Procedure 2: Visual Display Test

This test has two parts. First, determine the ideal font-size, text, and background color for the smart mirror's display. Second, to determine if the smart mirror's display provides clear visual feedback.

3.2.1 Visual Display Test (Trial 1)

The participants must have 20-20 or 20-20 correct vision for this test. Rows of random letters in Verdana font are displayed on the screen, ranging in font size from 10-point to 50-point. The smart mirror's visual display uses Verdana font, the client's preference. Table 8 contains a summary of the four testing combinations. Participants will read the rows of letters aloud and evaluate the clarity of the three text/background combinations, recording their preferred color combination.

Table 8 - Four Variations Testing Combinations for Trial 1 of the Visual Display Test

Font Name	Range of Font Sizes	Text Color	Background Color
Verdana	12-40	White	Black
Verdana	12-40	Black	White
Verdana	12-40	White	Dark grey
Verdana	12-40	Light blue	Dark grey

After conducting this test, it was determined that the ideal color combination is white text color on a black background, using a minimum of 20-point font size. The results from the trial are in Table 9.

Table 9 - Results of the Visual Display Test, Trial 1

Participant X	Accuracy (%)						Preferred color combination
	Font Size (pt)	10	20	30	40	50	
Participant A		90	100	100	100	100	White text/black background
Participant B		95	100	100	100	100	White text/black background
Participant C		85	100	100	100	100	White text/black background
Participant D		95	100	100	100	100	White text/black background

3.2.2 Visual Display Test (Trial 2)

For this test, participants stand two feet from the smart mirror and view the mirror's display. The display's words are in a white Verdana font, size minimum of 20-point, and the display's background color is black. The pass criteria for this requirement is that the user can read the text with 100% accuracy when standing two feet from the mirror.

After conducting this test, the result is that 100% of the display was readable for all participants. Therefore, the pass criteria were met, and the requirement was satisfied.

3.3.0 Procedure 3: Keypad Accuracy Test

This test ensures that the smart mirror responds correctly to a key press. This test can occur while coding the functionality of the smart mirror. After coding a key, press the key and observe the corresponding function. If the expected result does not occur, the code must be adjusted and the key tested again. This test also accounts for various edge cases. A summary of edge cases is in Table 10. If the expected result does not occur, adjust the code, and run the edge case again. This process repeats until each key functions as expected. The pass criteria for this requirement is that each key initiates the correct function when activated.

Table 10 - Edge Cases and Expected Results

Edge case	Expected result
The user is on the Home Screen; user presses Exit	Nothing occurs
The user is on the Home Screen; user presses Forward	Nothing occurs
The user is on the Home Screen; user presses Back	Nothing occurs
The user is on the Home Screen; user presses an unused key	Nothing occurs
The user is on the Task Screen; user presses any Task key	Nothing occurs
The user is at the start of a task; user presses Back	Nothing occurs
The user is on the Task Screen; user presses an unused key	Nothing occurs

After the test, the pass criteria were met, and the requirement was satisfied.

3.4.0 Procedure 4: Keypad Response Test

This test ensures that the keypad has a timely response. Measure the response time of each key by pressing the key and recording the time it takes for the corresponding function to occur. The pass criteria for this test is that the corresponding function initiates in less than one second after activating the key.

After conducting the test, the corresponding function was observed in less than 0.5 seconds after key activation. Therefore, the pass criteria were met, and the requirement was satisfied.

3.5.0 Procedure 5: Motion Sensor Test

This test ensures the smart mirror is awake when the user is in front of the mirror. To test this, participants walk into the room, approach the mirror, and stand 2 ft in front of the mirror. Then the participants perform a task. The user records the distance they are from the smart mirror when the smart mirror awakes and when the smart mirror sleeps. The pass criteria (requirement) for this test is that the smart mirror is awake when the user is in front of the mirror. However, the objective is for the smart mirror to wake up when the user enters the washroom.

After conducting the test, the observation is that the smart mirror wakes when the user enters the washroom. Therefore, the pass criteria were met, and the requirement was satisfied. A summary of the results is in Table 11.

Table 11 - Results of the Motion Sensor Test

Participant X	When did the smart mirror wake?	When did the smart mirror sleep?
Participant A	~4 ft away from the mirror	After ~ 10 min of no motion
Participant B	~4 ft away from the mirror	After ~ 10 min of no motion
Participant C	~4 ft away from the mirror	After ~ 10 min of no motion
Participant D	~4 ft away from the mirror	After ~ 10 min of no motion

3.6.0 Procedure 6: Temperature and Relative Humidity Tests

The purpose of these tests is to ensure that the internal electronics do not exceed their maximum working temperature ($T > 40^{\circ}\text{C}$) or relative humidity ($\text{RH} > 30\%$). A smart mirror model, shown in Figure 19, is built for this test to monitor the internal T and RH of the model for five days.



Figure 19. Model of the Smart Mirror used for Testing

A hygrometer inside the model automatically measures constant T and RH measurements on a graph. Additionally, manually record the bathroom's T and RH before and after showers to observe the effect of the ambient environment on the internal environment of the smart mirror. These tests occur in a bathroom, shown in Figure 20, including a bathtub, shower, and sink. The pass criteria of these tests are that the internal temperature and relative humidity do not exceed 40°C and 30%, respectively.

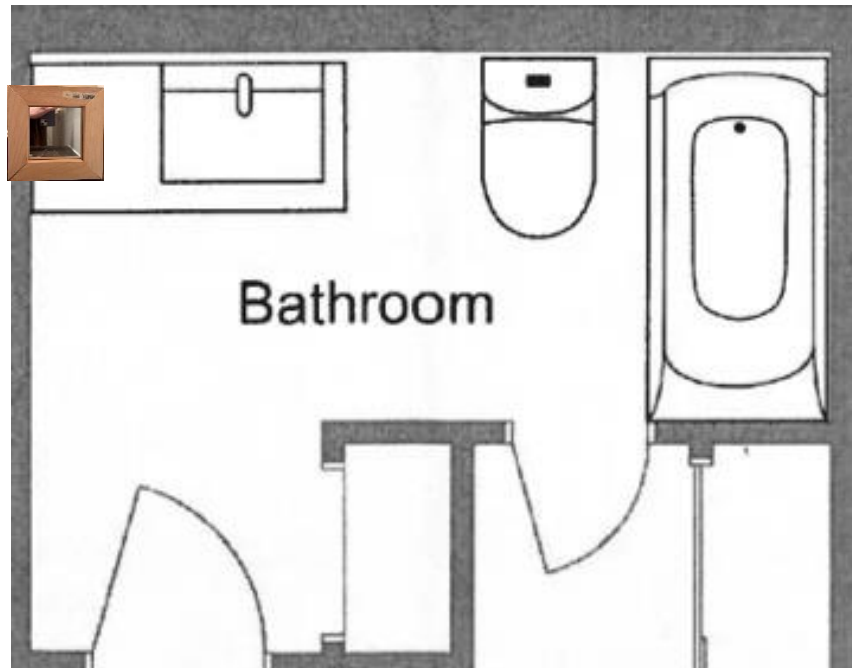


Figure 20. Layout of the bathroom used for the temperature and humidity testing with downsized mirror model resting on the sink counter

After conducting the tests, it was determined that the pass criteria were met and the requirements were satisfied. The temperature and relative humidity test results are in Tables 12 and 13, respectively.

Table 12 - Results from the Temperature Test

	Ambient Temperature	Internal Temperature
Day 1		
Before shower:	23.9 °C	24.5 °C
After a 20-minute shower:	23.9 °C	25 °C
Day 2		
Before shower:	23.8 °C	24.6 °C
After a 45-minute shower:	25.4 °C	24.9 °C
Day 3		
Before shower:	23.3 °C	24.2 °C
After a 75-minute shower:	26.1 °C	25.7 °C
Day 4		
Before shower:	22.4 °C	23 °C
After a 55-minute shower:	23.5 °C	23.4 °C
Day 5		
Before shower:	24 °C	25.3 °C
After a 50-minute shower:	25.5 °C	26.6 °C

Table 13 - Results from the Relativity Humidity Test

	Ambient Humidity	Internal Humidity
Day 1		
Before shower:	20%	22%
After a 20-minute shower:	70%	22%
Day 2		
Before shower:	29%	22%
After a 45-minute shower:	89%	22%
Day 3		
Before shower:	17%	22%
After a 75-minute shower:	95%	24%
Day 4		
Before shower:	15%	22%
After a 55-minute shower:	79%	22%
Day 5		
Before shower:	34%	25%
After a 50-minute shower:	87%	25%

3.7.0 Two-Way Reflective Material Test

The purpose of this test was to determine the ideal two-way reflective material. There were four samples to test: smart mirror glass, two-way reflective acrylic, and two-way reflective glass. Each sample was placed against the monitor's screen so participants could record their opinion of the sample's reflectivity and transparency. After conducting this test, the ideal two-way reflective material was determined to be smart mirror-specific glass.

3.8.0 Review with Project Relevant Professionals

In addition to the seven requirement tests and reflective material test, a review of the design's function, aesthetic, and ease of use occurred with four occupational therapists. The questions presented to the occupational therapists were as follows:

1. Which type of client from your client base do you think would use this smart mirror?
2. Would your client find this smart mirror and keypad straightforward? How could the user interface be improved?
3. Are the designs of each icon sufficient? Yes/No. If not, how can they be improved?
4. Do you believe the progress bar displayed on the smart mirror will help motivate your client? Yes/No. If not, how can this be improved?
5. Are the instructions for each step sufficient? Yes/No. If not, how can they be improved?
6. Is all the necessary and important information shown on the smart mirror's display? Yes/No, if no, what should be added/removed?
7. Can you think of any points of frustration that your client would experience while using the smart mirror?
8. Are there any parts of the smart mirror that would distract your client?
9. What customizations should be included in future revisions?
10. Any additional comments/questions/concerns?

A summary of the comments made throughout the reviews can be found in Table 14.

Table 14 - Summary of Comments from the Review

	Professionals 1+2	Professional 3	Professional 4
Question 1	n/a	Children with traumatic brain injuries at a reading age of grade 5	Adult patients recovering from a stroke
Question 2	Simple to use	Concerned about the sturdiness	Simple to use
	Customizable icons would be good		Customizable icons would be good
Question 3	Yes, given the availability for customization	Very self-explanatory, but not all users will have good enough dexterity	Yes, given the availability for customization
Question 4	Very individual. Some may like it; others may not	For children, some sort of "sticker" reward may be better	For some clients, it could be helpful, but for others, it could cause frustration
			The use of sound for motivation could be a good alternative
Question 5	Yes, given the availability for customization	Being able to customize is good, but the process would need to be intuitive	Yes, given the availability for customization
			Not all patients will need cueing; for some, a checklist will provide enough assistance
Question 6	Yes	Yes, but photos would be better for children	Yes, but the addition of video guidance for steps could be a good addition
Question 7	Using the mirror every time they wash their hands may get tiresome	Children may get by the task counters	The progress bar may make some users feel pressured to rush through tasks
Question 8	n/a	n/a	n/a
Question 9	n/a	Find ways to make it more fun and engaging for kids	Customize user interface
			Options for audio guidance
		Add in encouragement after completing each step and have the option to adjust the amount of encouragement	Customization of tasks offered, and the wording used for steps
			Addition of videos for step-by-step guidance
Question 10	Making sure the keypad placement is adjustable	Allow the clients to customize the steps and add more tasks	Chose to keep the steps or use the mirror for a checklist only
	Potential for different types of user interface		Chose to use the progress bar or not
Question 10	Making sure the keypad placement is adjustable	Allow the clients to customize the steps and add more tasks	Making sure the keypad placement is adjustable
	Potential for different types of user interface		Potential for different types of user interface

3.7.0 Summary

In summary, a smart mirror was developed to cue individuals as they complete hygienic tasks in the bathroom. There were eight requirements tests, concluding that the mirror passed each requirement. In addition to the requirement testing, four occupational therapists provided feedback through in-person demonstrations and a discussion period with specific focus questions. The overall feedback from the occupational therapists was that the mirror has the potential to guide their patients' given further development with customization options. Some ideas for further customization include using videos and audio for guidance, creating a custom user interface, and tailoring the tasks and steps displayed on the screen to suit individual patients.

4.0 Risk Analysis

There are two main areas where risks may arise. The first, in Table 15, are risks associated with the function of the smart mirror. The second, in Table 16, are risks associated with the project plan.

Table 15 - Risks Associated with Mirror Functions

Requirement	Potential Failure Mode	Potential Cause of Failure	Potential Effect of Failure	Mitigation Strategy
The smart mirror functions properly in a bathroom environment	The electronics cease to function optimally	High humidity and temperature levels can cause electronics to malfunction	The mirror will lose functionality	Use water-resistant components or a protective case
The smart mirror wakes using a motion sensor	The motion sensor is not sensitive enough, and the mirror falls asleep with the user in front of it	Incorrect sensitivity coded for the sensor Placing the sensor behind the glass may affect its function	The smart mirror will not turn on when the user stands in front of the mirror	Re-code the sensor Building a case for the sensor outside of the mirror's frame
The program correctly activates the function selected by the user	When a user selects a task, the button takes them to a different task, or nothing happens	Incorrect coding of the function's pathway Typo in code resulting in a bug	The mirror will not provide beneficial assistance to the user	Test button functionality while coding to catch bugs early on
Icons convey the function of each key	If an icon's function is unclear, the user will have difficulty using the interface	User is unable to select their desired task because they do not understand what button to activate	The mirror will not be able to provide any assistance to the user	Discuss icon design with occupational therapists Use stickers for the prototype. There is an option for personalized icon stickers

Table 16 – Risks Associated with Project Planning

Requirement	Potential Failure Mode	Potential Cause of Failure	Potential Effect of Failure	Mitigation Strategy
Purchase all of the supplies before beginning construction of the physical design	Supply delay	Delay in shipping materials	Unable to complete the design within the given time constraint due to difficulties with the assembly	Establish an internal 4-week lead time on all purchases to prevent delays in manufacturing
		Certain supplies are out of stock		Order supplies from within Canada
	The parts are incorrect	Misread product details	The prototype was unable to function properly, leading to testing failure	Carefully review the material sheet
		Ordered substandard products		Verify product information prior to placing an order
	Part damage occurs	Products damaged during shipping	Unable to function properly, causing testing failure	Order extra parts
Stay under budget (\$2000)	The remaining funds could not meet our needs	Incurred additional costs due to factors such as increased supply needs	Not enough funds to finish the prototype	Check the bill of materials carefully before placing an order
The design team has the technical capability to handle the project's complexity.	The capstone team members are not computer science professionals and may not be able to code to the client's specific requirements	The requested functionality requires a high level of computer programming skill	The project may be incomplete within the set period Functionality may not meet client's requests	Consult with individuals that have more computer programming experience

Requirement	Potential Failure Mode	Potential Cause of Failure	Potential Effect of Failure	Mitigation Strategy
The prototype meets the client's expectations	The prototype does not meet the client's expectations	Coding difficulty and limitations	The design fails to fulfill the client's requirements	Communicate with clients about design ideas. Provide clients with progress updates

5.0 Project Limitations

The first limitation is that using the keypad requires the user to have fine-motor skills due to the small size of the keys. Any users with limited mobility or control of their fingers would find it difficult to control the mirror. Additionally, testing is limited to the general functionality of the mirror, so while the mirror can provide step-by-step guidance for hygiene tasks, the hypothesis that it could benefit individuals with MCI is yet to be confirmed.

Concerning the physical design of the smart mirror, the aesthetic has limitations due to the project's budget, using screws and spray paint instead of a joint connection method and high-quality wood paint. The design has limitations due to the physical location; the bathroom in the Smart Suite has a counter, so the smart mirror requires a countertop for support. Additionally, the mirror requires two power outlets, one for the Raspberry Pi and one for the monitor. While the Smart Suite can support this, it may be inconvenient if placed in other washrooms. Lastly, the smart mirror prevents moisture buildup inside the frame but does not eliminate moisture.

The last area of limitations comes from the software. Due to security measures of web forms, the user metrics are accessible in the web console directly on the mirror, which is inconvenient for clinicians wanting this information. Also, customizations can only happen using the JavaScript file, which would require a basic knowledge of the programming language.

6.0 Project Recommendations

Based on the smart mirror's limitations, the proposal of recommendations is in Table 17.

Table 17 - Summary of Project Limitations and Recommendations

Physical Build Limitation	Recommendation
Using the keypad requires fine-motor skills (e.g., Dexterity)	Create a custom user interface
The budget limits the mirror's aesthetic	Eliminate screws by using joints to secure the frame
	Use a hardwood (instead of softwood) for the final product
	Use high-quality staining to finish the wood
Requires two power outlets to power the mirror	Connect the microcontroller and monitor to one power supply cord
The current design assumes that the mirror will be resting on a shelf/countertop	Add additional mounting brackets to allow for the mirror to be secured higher up on the wall

Physical Build Limitation	Recommendation
Cannot eliminate water vapor efficiently	Design a fan system within the frame
Software Limitation	Recommendation
Software testing was limited to the overall functionality	Perform testing with individuals living with MCI and adjust the display based on testing results
User metrics are accessible in the console	Redesign the display with Python, which can write metrics into a text file
Customization of the tasks and steps occurs within the JavaScript code file	Create an app integrated within the mirror

7.0 Summary

Individuals living with MCI experience challenges completing personal hygiene tasks due to various executive functioning problems. While a caregiver can help these individuals by providing reminders and instructions, dependency on a caretaker decreases independence, which can negatively impact self-confidence. The design team believes this smart mirror could help individuals with MCI complete hygienic tasks and support independent living.

Due to scope limitations, the mirror assists with six tasks: brushing teeth, flossing teeth, washing face, washing hands, applying deodorant, and brushing hair. The smart mirror reminds the users of their daily hygiene tasks and provides step-by-step cueing when they activate a task using the keypad.

Testing was completed to ensure the mirror functions effectively. There were also tests to ensure internal temperature stayed below 40°C and internal relative humidity stayed below 30%. Additionally, the mirror was brought to the Smart Suite for a review by occupational therapists. This review affirmed the functionality of the mirror, and merit was seen in the overall design and idea. However, this product is intended to be a proof-of-concept; therefore, further testing and development is required.

The main recommendation is for testing to occur with individuals who live with MCI to conclude the effectiveness of a smart mirror in increasing the independence of this population. In addition, recommendations to improve the physical build and software were made. To conclude, the design team has met the requirements set for the project and have produced a smart mirror capable of assisting with personal hygiene tasks.

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Appendices

The following appendixes include additional information regarding the smart mirror project, such as the bill of materials and the project timeline (Appendices A and B, respectively). Decision matrixes in Appendix C clarify the choices of building materials, while Appendix D describes the building procedure. Appendixes E and F relate to the development of the software.

Appendix A – Bill of Materials

Table 19 provides a break down of the total cost of the smart mirror project.

* Total price subject to Manitoba taxation; Exchange rate for Euros and USD to CAD on December 11, 2022, shipping not included.

Table 18 - Smart Mirror Bill of Materials

Smart Mirror (Display)							
Item	Qty	Unit Price (CAD)	Total Price (CAD)	Distr.	Distr. P/N	Mfr.	Mfr. P/N
Display Monitor	1	399	446.88	Dell	210-BBCK	Dell	75M5M
Smart Mirror Glass	1	586.87 (USD)	801.66	Two Way Mirrors	NA.	Two Way Mirrors	NA.
1 x 4 x 6 Pine Wood	1	12.28	13.75	Home Depot	B 1000 115597	Home Depot	B 1000 115597
1 x 4 x 8 Pine Wood	1	16.43	18.40	Home Depot	X 1000 115600	Home Depot	X 1000 115600
Mdf panel	1	8.58	9.61	Home Depot	0798159	Alexandria molding	NA.
#8 1 ½" wood screw	1	3.47	3.89	Home Depot	10001815 74	Paulin	848-517
#8 ½" wood screw	1	3.47	3.89	Home Depot	62241201 8673	Paulin	N.A.
Raspberry Pi case	1	14.99	16.78	Geek Pi	B07PQJG GGN	Geek Pi	B07PQJG GGN
Hydrophobic Mesh	1	12 (Euro)	17.24	Material Sample Shop	B042HY	Material Sample Shop	B042HY
Stain	1	12.98	14.53	Home Depot	NA.	Varathane	WPS172214 4
Wood Sealer	1	34.97	39.17	Home Depot	420813	Olympic	00440122
Wood Filler	1	14.91	16.70	Home Depot	10015534 94	DAP	7079874889 7
Black Spray Paint	3	13.87	46.60	Dollarama	0201773	DecoArt	0076621801 3750
Humidity test strip	1	13.99	15.67	Amazon	B01M30V DLK	Bartovation	PGA01V10 0
Painter Tape	1	2	2.24	Dollarama	3100144	Duramax	0005921298 7364

Raspberry Pi 3 B+	1	35	39.20	Digi – Key Electronics	2648 - RASPBERRYPI3-ND	Raspberry Pi	RASPBERRY PI 3 MODEL B BCM2830
Item	Qty	Unit Price (CAD)	Total Price (CAD)	Distr.	Distr. P/N	Mfr.	Mfr. P/N
Keypad	1	14.99	16.80	BestBuy	12408881	Insignia	NS-PNKNUM19-C
Motion Sensor	1	9.39	10.52	Amazon	B07GJDJ V63	Onyehn	8741774811
HDMI cord	1	11.82	13.24	Digi-Key Electronics	2648-SC0531-ND	Raspberry Pi	SC0531
Power Cord	1	8	8.96	Digi-Key Electronics	2648-RPIUSB-CPOWER SUPPLYBLACKUS-ND	Raspberry Pi	RPI USB-C POWER SUPPLY BLACK US
Micro SD Card	1	17.99	20.15	Best Buy	16373385	SanDisk	SDSQXCU-064G
Furniture L Shape bracket	1	9.99	11.12	Amazon	a16080800ux0287	Dragonmart s	a16080800ux0287

Grand total (CAD):	1587.00
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Appendix B – Timeline and Work Breakdown Structure

The project timeline is in Table 20, with a link for the corresponding Gantt Chart: [Gantt Chart.mpp](#)

Table 19 - Smart Mirror Project Timeline

Task Name	Duration	Start	Finish
Smart Mirror	145 days	Tue 22-09-13	Mon 23-04-03
Problem Definition & Research	15 days	Tue 22-09-13	Mon 22-10-03
Gather Background Information	15 days	Tue 22-09-13	Mon 22-10-03
Cognitive Impairments	15 days	Tue 22-09-13	Mon 22-10-03
Existing Smart Mirrors	15 days	Tue 22-09-13	Mon 22-10-03
Clients	15 days	Tue 22-09-13	Mon 22-10-03
Existing Assistive Technology	15 days	Tue 22-09-13	Mon 22-10-03
Interviews	13 days	Tue 22-09-13	Thu 22-09-29
Clients	13 days	Tue 22-09-13	Thu 22-09-29
Professionals	8 days	Tue 22-09-20	Thu 22-09-29
Identify Objectives & Constraints	6 days	Tue 22-09-13	Tue 22-09-20
Identify Stakeholders	6 days	Tue 22-09-13	Tue 22-09-20
Idea Generation	9 days	Mon 22-10-03	Thu 22-10-13
List of Daily Tasks	9 days	Mon 22-10-03	Thu 22-10-13
Brainstorm Lists of Tasks	4 days	Mon 22-10-03	Thu 22-10-06
Discuss with Clients	1 day	Fri 22-10-07	Fri 22-10-07
Breakdown Tasks into Steps	5 days	Sat 22-10-08	Thu 22-10-13
Brainstorm User Interfaces	9 days	Mon 22-10-03	Thu 22-10-13
Inputs	9 days	Mon 22-10-03	Thu 22-10-13
Outputs	9 days	Mon 22-10-03	Thu 22-10-13
Decision-Making & Design Selection	40 days	Fri 22-10-14	Thu 22-12-08
Select One Conceptual Design	5 days	Fri 22-10-14	Thu 22-10-20
Software & Hardware	5 days	Fri 22-10-14	Thu 22-10-20
Physical Build	5 days	Fri 22-10-14	Thu 22-10-20
Mirror Display Layout	5 days	Fri 22-10-14	Thu 22-10-20
Project Plan Revision 1	5 days	Fri 22-10-14	Thu 22-10-20
Sketches	5 days	Fri 22-10-14	Thu 22-10-20
Bill of Materials	5 days	Fri 22-10-14	Thu 22-10-20
Risk Analysis	5 days	Fri 22-10-14	Thu 22-10-20
Evaluation & Testing	5 days	Fri 22-10-14	Thu 22-10-20
Summary & Recommendation	5 days	Fri 22-10-14	Thu 22-10-20
Design Review	26 days	Tue 22-10-25	Tue 22-11-29
Preparation	26 days	Tue 22-10-25	Tue 22-11-29
Presentation	26 days	Tue 22-10-25	Tue 22-11-29
Project Plan Revision 2	33 days	Tue 22-10-25	Thu 22-12-08
Revision History	33 days	Tue 22-10-25	Thu 22-12-08
Project Specific Materials	33 days	Tue 22-10-25	Thu 22-12-08
Design Development	83 days	Fri 22-10-21	Tue 23-02-14
Final Drawings	8 days	Fri 22-10-21	Tue 22-11-01

Task Name	Duration	Start	Finish
Mirror Display	8 days	Fri 22-10-21	Tue 22-11-01
Physical Mirror	8 days	Fri 22-10-21	Tue 22-11-01
Block Drawing	8 days	Fri 22-10-21	Tue 22-11-01
Order Parts	4 days	Wed 22-11-02	Sun 22-11-06
Coding	72 days	Mon 22-11-07	Tue 23-02-14
Physical Build	67 days	Mon 22-11-14	Tue 23-02-14
Testing & Analysis	25 days	Tue 23-02-14	Mon 23-03-20
Professional Consulting	8 days	Wed 23-02-15	Fri 23-02-24
User Experience & Feedback	7 days	Mon 23-02-20	Tue 23-02-28
Implement Changes	25 days	Tue 23-02-14	Mon 23-03-20
Final Design	10 days	Tue 23-03-21	Mon 23-04-03
Review Design	4 days	Tue 23-03-21	Fri 23-03-24
Final Assembly	7 days	Sat 23-03-25	Mon 23-04-03
Design Presentation	6 days	Sat 23-03-25	Mon 23-04-03
Make PowerPoint	7 days	Sat 23-03-25	Mon 23-04-03
Prepare Oral Presentation	7 days	Sat 23-03-25	Mon 23-04-03

Appendix C – Decision Matrixes

A.C1 Choice of Programming Language

A decision matrix was used to decide on the programming language. Five weighted criteria were chosen; the bigger the weight, the more important the criteria are to the project. Then, each of the three languages options was evaluated for every criterion and given a rating based on this scale:

1.0 = not ideal, 0.25 = poor, 0.5 = acceptable, 0.75= good, 1.0 = Ideal

The choice of programming language in Table 21 is JavaScript, CSS, and HTML.

Table 20 - Programming Language Decision Matrix

Criteria	Weight	JS, CSS, HTML	Python	MagicMirror
Prior Experience	0.1	0.75	0.5	0.0
Interactive Ability	0.3	1.0	1.0	0.0
Functionality	0.3	1.0	0.75	0.25
Style Ability	0.2	0.75	0.5	1.0
Online Help	0.1	0.75	0.5	1.0
Total	1.0	0.9	0.725	0.375

Prior experience relates to the team's experience and comfort level with the programming language. Interactive ability is the measure of customizability options and user input capabilities. Functionality measures the ease with which the language can achieve the software requirements. Style ability is a measure of aesthetic appeal that the coding language can achieve. Online help is correlated to the availability of online databases that assist with troubleshooting.

A.C2 Choice of Hardware

A decision matrix was used to decide on the hardware. Four weighted criteria were chosen; the bigger the weight, the more important the criteria are to the project. Then, each of the three hardware options was evaluated for every criterion and given a rating based on this scale:

1.0 = not ideal, 0.25 = poor, 0.5 = acceptable, 0.75= good, 1.0 = Ideal

The decision matrix for software, in Table 22, determined Raspberry Pi with the monitor as the ideal hardware.

Table 21 - Hardware Decision Matrix

Criteria	Weight	Raspberry Pi w/ monitor	Apple iPad Air	Dell Laptop
Graphics Processing	0.2	0.75	0.75	0.75
Compatibility with External Devices	0.4	1.0	0.0	1.0
Cost	0.3	1.0	0.25	0.75
Size	0.1	1.0	0.5	0.5
Total	1.0	0.95	0.275	0.825

The graphics processing is a measure of each hardware's GPU. The compatibility with external devices measures the possibility of connecting to the Raspberry Pi and keypad. Each piece of hardware was researched, and the lowest cost was rated at 1.0. Size measures whether the hardware comes in the ideal size or not.

A.C3 Choice of Framing Material

A decision matrix was used to decide on the framing material. Nine weighted criteria were chosen; the bigger the weight, the more important the criteria are to the project. Then, each of the three hardware options was evaluated for every criterion and given a rating based on this scale:

1.0 = not ideal, 0.25 = poor, 0.5 = acceptable, 0.75= good, 1.0 = Ideal

The decision matrix for framing material in Table 23 determined softwood to be ideal.

Table 22 - Framing Material Decision Matrix

Criteria	Weight	Aluminum	Medium Density Fiber Board	Hardwood	Softwood
Strength	0.2	1.0	0.5	1.0	0.5
Weight	0.2	0.0 (2.7 g/cm ³)	0.5 (0.75 g/cm ³)	0.7 (0.6 g/cm ³)	1.0 (0.3g/cm ³)
Thermal Conductivity	0.05	0.75 (120 W/m-K)	0.25 (0.16 W/m-k)	0.25 (0.3 W/m-K)	0.25 (0.14 W/m-K)
Cost	0.2	0.0	0.75	0.5	1.0
Easy to Build With	0.05	0.25	1.0	0.75	1.0
Availability	0.05	0.5	0.75	1.0	1.0

Resistance to Humidity	0.15	1.0	0.75	0.5	0.25
Maintenance	0.05	1.0	0.75	0.5	0.25
Aesthetic Appeal	0.05	0.5	0.75	1.0	1.0
Total	1.0	0.5	0.6255	0.69	0.7125

The strength of each material was researched to compare and rank each material accordingly. Then the densities of each material were compared to determine the lightest material. Thermal conductivity measures if the material is an insulator (low thermal conductivity) or conductive; the ideal material would conduct heat away from the mirror. The average cost was compared for each material and ranked accordingly. Ease to build considers the tools and additional maintenance (like staining) required when building with each material. The availability measures how easy it is to find the material in the proper sizes. The resistance to humidity measures how the material responds (warping or not) to humid conditions. Maintenance measures how much maintenance is required once the product is built. Aesthetic appeal is how the material looks when properly finished.

A.C4 Choice of Two-Way Reflective Material

A decision matrix was used to decide on the two-way reflective material; Six weighted criteria were chosen. The bigger the weight, the more important the criteria are to the project. Then, each of the three hardware options was evaluated for every criterion and given a rating based on this scale:

1.0 = not ideal, 0.25 = poor, 0.5 = acceptable, 0.75= good, 1.0 = Ideal

The decision matrix for two-way reflective material, in Table 24, determined the smart mirror glass to be the ideal material.

Table 23 - Two-Way Reflective Material Decision Matrix

Criteria	Weight	Glass	Acrylic	Glass Smart Mirror	Infinity Mirror Film
Cost	0.05	0.75 (\$430)	0.0 (\$700)	0.25 (\$590)	1.0 (\$270)
Reflectivity: Transparency	0.35	0.25	0.75	1.0	0.5
Effort of Installation	0.05	1.0	1.0	1.0	0.25
Distortion	0.25	1.0	0.25	1.0	0.25
Hardness (scratch resistance)	0.2	1.0	0.25	1.0	0.25
Weight	0.1	0.0 (7.492 kg)	1.0 (1.680 kg)	0.75 (3.716 kg)	0.75 (3.716 kg)
Total	1.0	0.625	0.6	0.938	0.425

The cost of each material was determined using the smart mirror glass store's website. The reflectivity to transparency ratio was determined by viewing the monitor behind each glass sample. The installation effort was simple; either the glass was placed inside the frame or, in the case of the mirror film, it was a lot more strenuous as it needed to be carefully laid onto a piece of glass. The distortion was determined by further research. Acrylic bends when it is in bigger pieces, simulating a fun house mirror. The infinity mirror film has great potential for distortion in the installation process. The hardness values

for each material were determined; the higher ranking means higher hardness, so the material is not easily scratched. The weight of the materials was also determined using the smart mirror glass store website.

Appendix D – Instructions for Building a Smart Mirror

A.D1 Materials

- Pinewood (1x4x96") x1
- Pinewood (1x4x72") x1
- Wood screws (#8, 1 ½") x 18
- Wood screws (#8, ½") x 14
- MDF panel (24x48x1/8") x1
- Monitor
- Motion sensor
- Two-way glass
- Hydrophobic mesh
- Sandpaper (250 and 450)
- Matte black spray paint
- Wood sealant
- Wood filler
- Button panel

A.D2 Tools

- Chop saw
- Table saw
- Bench drill press
- Electrical Screwdriver
- Drill bits 11/64"
- T-Square
- Tape measure
- Pencil
- Glue
- Filler knife
- Scissors
- Paper tape

A.D3 Procedure

* These instructions are a general guide; use them at your own risk.

1. Cut two 16 ¾" wood pieces from the 96" length wood with a chop saw.
 - Use a table saw and create a groove with a thickness of 3/8" using a 3/8" thick blade. The location of the groove will be ½" from the edge of the width for each wood piece.
2. Cut two 28 ¼" wood pieces from the 96" length wood with a chop saw.
 - For each piece of wood, drill two sets of 4 ventilation holes, each set of holes with 1 ½" diameter; the first hole was drilled 2" away from the edge in the axial direction, one ¾" from the edge in the lateral direction and spaced 2" apart on each side. The same applies to the second set of ventilation holes on the other side of the wood piece.
 - For the wood piece, which will be placed on the left side of the frame from the front view, at the bottom set ventilation holes, make an extra hole with 1" diameter using a drill press; the hole will be placed 2" away and aligning from the 1 ½" diameter hole.
 - For the wood piece, which will be placed on the right side of the frame from the front view, at the bottom set ventilation holes, make an extra hole with ¾" diameter using a drill press; the hole will

- be placed 2" away and aligning from the 1 ½" diameter hole.
3. After all the holes are drilled, use a table saw and create a groove with a thickness of 3/8" using a 3/8" thick blade. The location of the groove will be ½" from the edge of the width for each wood piece. The end product should look like Figure 22.



Figure 21. Cut side pieces for the frame

4. Cut one of 16 ¾" pieces from the 96" length wood with a chop saw.
5. Cut eight pieces of 6" wood from the 72" length wood with a chop saw.
 - Trim each of the 6" wood pieces from the width of 3 ½" to 1 3/8" with a table saw.
6. Cut the MDF panel to 18 ¼" x 28 ¼".
7. Remove any rough edges through wood filling and sanding to prepare the frame.
 - Apply an appropriate amount of filling material to the rough edges and wood gaps; spread the wood filling evenly using a filler knife. Once the filling material has dried off, use 250 sandpaper to sand down all wood pieces first, then refine the sanding process with 450 sandpaper to provide a smooth finish to the wood.
8. Then, apply the wood sealant onto every side of each piece using a paintbrush, then leave the wood pieces for at least a day to dry off.
9. For the 28 ¼" wood pieces, use scissors to cut the hydrophobic mesh and use glue to install the mesh onto the 1 ½" diameter holes on the grooved side of the wood piece.
10. The next step is to apply black paint onto all the wood pieces, apply matte black spray paint onto all sides for every wood piece, then leave the wood pieces for at least a day to dry off. After the paint has dried off, use 450 sandpaper to sand down all the wood pieces again to ensure a smooth surface.
11. Paint one side of the MDF panel using black spray paint to provide a dark background.

Assembling:

12. Connect one of the $28 \frac{1}{4}$ " wood pieces and two of $16 \frac{3}{4}$ " wood pieces using two $1 \frac{1}{2}$ " screws between each $16 \frac{3}{4}$ " wood piece. Before connecting the wood pieces, line up all the grooves first, then use a drill bit to predrill the wood pieces.
 - Place the first screw $\frac{3}{4}$ " away from the edge of the non-grooved side and the second screw $2 \frac{1}{4}$ " away from the non-grooved edge. Both screws will be placed $\frac{3}{8}$ " from the edge in the axial direction, as shown in Figure 23. The same applies to the other $16 \frac{3}{4}$ " wood piece.

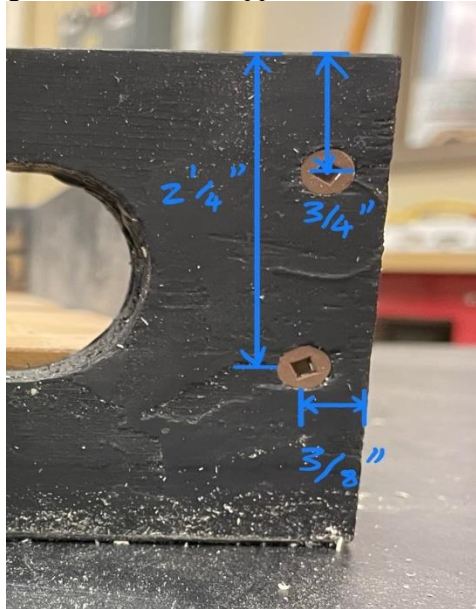


Figure 22. Placement of screws for side pieces

13. Once the basic "C" structure is built, slide the two-way glass into the grooves, as in Figure 24.



Figure 23. Demonstration of how to install the two-way glass

14. To finish framing, insert the other 28 $\frac{1}{4}$ " wood piece onto the C shape frame and apply the 1 $\frac{1}{2}$ " long screws as in step 1. The completed frame will appear in Figure 25.

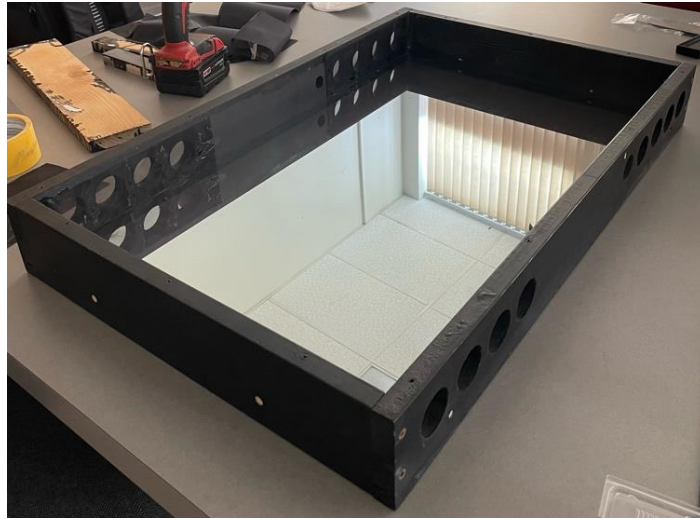


Figure 24. Example of the completed mirror frame

15. Place the 6" support pieces in all four corners of the two-way glass; each corner will have two support pieces, as shown in Figure 26.



Figure 25. Placement of the corner support pieces

16. Drill each support into the frame; the 28 $\frac{1}{4}$ " wood pieces will have a 1 $\frac{1}{2}$ " screw drilled 3" away from the edge in the axial direction and 2 $\frac{1}{4}$ " from the non-grooved side, as in Figure 27.

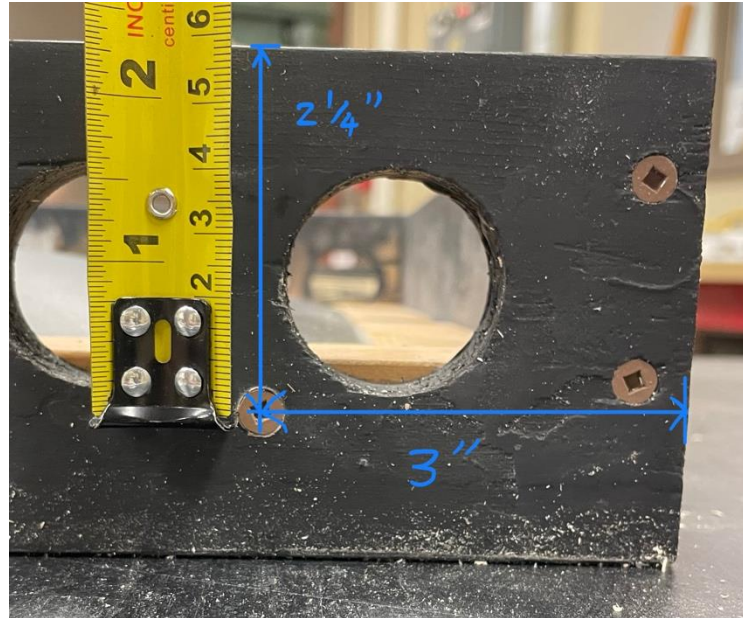


Figure 26. Dimensions for support screw placement

17. The supports by the 16 $\frac{3}{4}$ " wood pieces will each have a 1 $\frac{1}{2}$ " screw drilled 5" away from the edge in the axial direction and 2 $\frac{1}{4}$ " from the non-grooved side, as in Figure 28.



Figure 27. Dimensions for support screw placement

18. Now, the monitor can be placed inside the frame, resting on the supports.
19. Afterward, place the 16 $\frac{3}{4}$ " wood piece on top of the monitor, and predrill the piece of wood 10 $\frac{3}{4}$ " away from the top side of the frame and then into the frame. Next, insert one of the 1 $\frac{1}{2}$ " screws on each side of the 16 $\frac{3}{4}$ " wood piece, demonstrated in Figure 29.



Figure 28. Placement of monitor back support

20. After securing the monitor, place the Raspberry Pi, as demonstrated in Figure 30, and connect the electronics.



Figure 29. Placement of the Raspberry Pi

21. Install the MDF panel backboard using 14 #8 1/2" wood screws; all predrilled using drill bits. The screw placement is in Figure 31.



Figure 30. Installation of the MDF backboard

Appendix E – Overview of the Code

This Appendix contains a description of the JavaScript functions and an overview of the variables in the code. Table 25 provides a summary of each of the JavaScript functions.

Table 24 - Summary of JavaScript Functions

Function Name	Function Purpose (when the function is called)
Time()	Creates a digital clock and date (continually running)
userSelection()	Listens for user input, which directs which function to call (continually running)
taskName()	Displays the task name (when the user selects a Task key)
showTaskStep()	Displays the step for the selected task (when the user selects Back or Forward)
progressBar()	Creates a progress bar and updates the progress bar (when the user progresses through the task with Back or Forward)
createProgressBar()	Shows the progress bar on the smart mirror (when the user starts a task)
destroyProgressBar()	Removes the progress bar from the display (when the user exits or completes a task)
destroyTaskList()	Removes the task list from the display (when the user starts a task)
showTaskList()	Shows the task list on the smart mirror (when the user exits or completes a task)
checkboxes()	Checks the box beside the corresponding task (when the user completes that task)
uncheckBoxes()	Uncheck the boxes beside all of the tasks (the "dailyReset" function calls this at 3 am)
countAttempt()	Counts how many times the user starts each task (when the user presses keys 1-6) Increments the corresponding variable "startTaskName."
countComplete()	Counts how many times the user completes each task (when the user reaches 100% on the tasks progress bar) Increments the corresponding variable "counterTaskName."
dailyReset()	Every day at 3 am, the program calls this function to reset all the count variables to 0 and uncheck all the checkboxes.

There are a series of "if" statements to control the code flow. The simplest pseudocode is "IF user presses key #, display arrayName [#]." Table 26 summarizes two arrays containing strings of information and 12 different counters.

Table 25 - Overview of Code Variables

Name	Data Type	Contents	Function
taskList	Array of strings	[name of task 1, task2, task3, etc.]	Access the appropriate task name corresponding to user input (pressing Task)
taskSteps	Array of Arrays	[written instructions for step1, step2, step3, etc for every task]	Access the appropriate instructions corresponding to user input (pressing Forward)
start(TaskName) i.e., startBrushTeeth, startFloss, etc.	Integer	One number for the task	Increments by one every time a task is started
counter(TaskName) i.e., countBrushTeeth, countFloss, etc.	Integer	One number for each task	Increments by one every time a task reaches 100%

Figure 32 shows the basic logic process of the code.

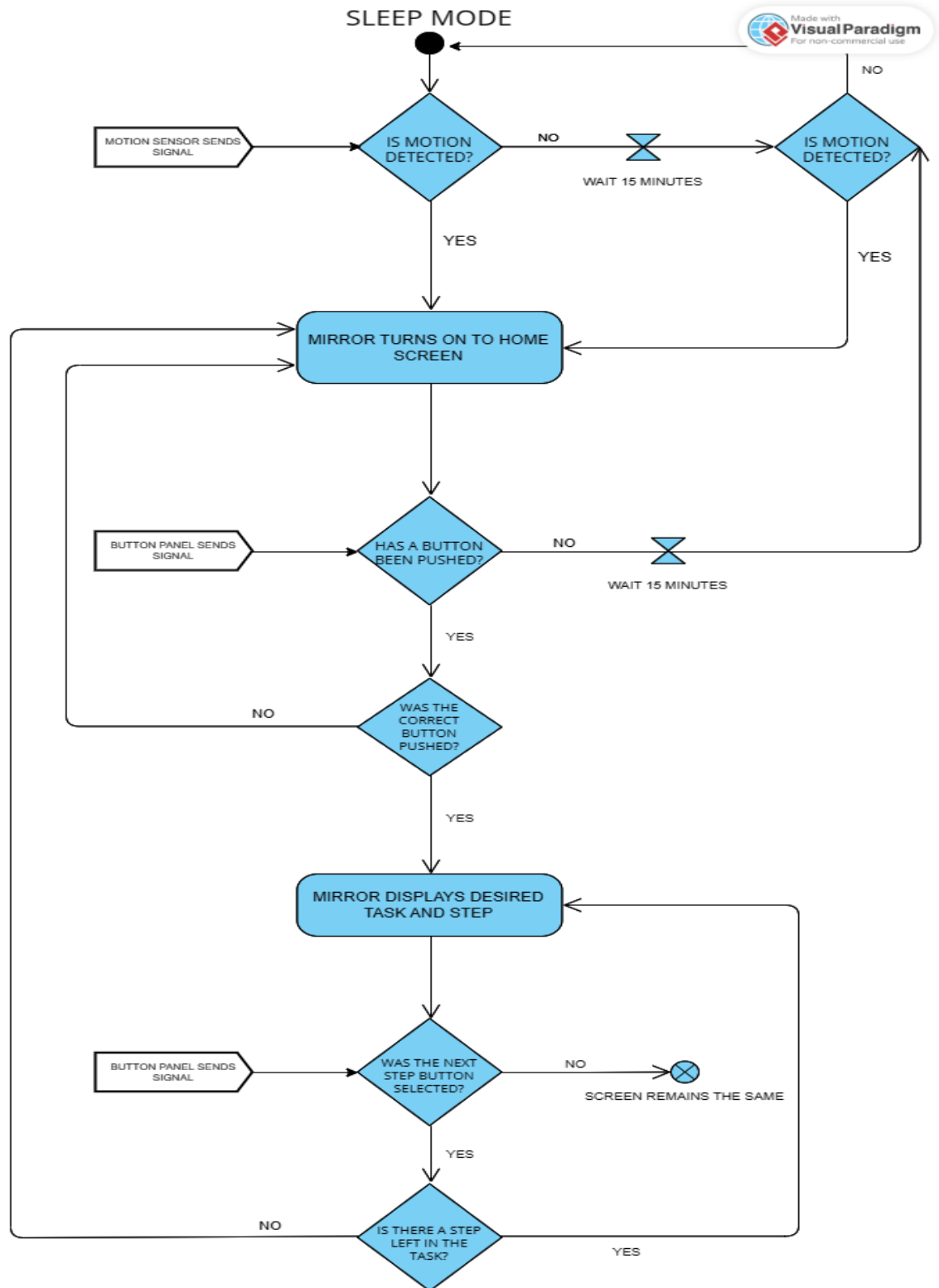


Figure 31. Activity sequence of the smart mirror software

Appendix F – Step-by-Step Cueing for Each Task

Occupational therapists helped determine the steps for each task, as shown in Table 27. These steps can be adjusted in the JavaScript file to meet the needs of individual patients.

Table 26 - Steps for the 6 Smart Mirror Tasks

Task	Brushing Teeth	Flossing Teeth	Washing Face	Washing Hands	Applying Deodorant	Brushing Hair
Step 1	Twist the cap off the toothpaste.	Pull out a line of floss.	Turn on the sink tap.	Turn on the sink tap.	Pick up deodorant.	Hold the brush at the top of your head.
Step 2	Squeeze one line of toothpaste onto the toothbrush.	Hold the floss with your thumbs and index fingers.	Wet washcloth.	Wet your hands under the stream of water.	Take the deodorant cap off.	Pull the brush down through your hair.
Step 3	Turn on the sink tap.	Place the floss between two teeth, and glide the floss up and down.	Dispense cleanser onto a washcloth.	Turn off the sink tap.	Lift arm to apply deodorant on one armpit, then the other."	Hold the brush on your head, and pull the brush down again.
Step 4	Wet toothbrush under the stream of water.	Repeat the process between each tooth.	Wipe your forehead with a washcloth.	Dispense soap onto your hand.	Put the deodorant cap on.	Repeat until all tangles are gone.
Step 5	Turn off the sink tap.	Throw floss into the garbage.	Wipe checks with a washcloth.	Rub hands together, and lather soap.	Put deodorant away.	Put brush away.
Step 6	Brush teeth for 2 minutes *2-minute timer displays*	Put the floss container away.	Wipe your chin with a washcloth.	Turn on the sink tap.		
Step 7	Spit out toothpaste		Using the water, rinse the cleanser off your face.	Wash hands together under the stream of water for 20 seconds		
Step 8	Turn on the sink tap.		Turn off the sink tap.	Turn off the sink tap.		

Task	Brushing Teeth	Flossing Teeth	Washing Face	Washing Hands	Applying Deodorant	Brushing Hair
Step 9	Rinse mouth and toothbrush with water.		Rinse the washcloth.	Dry your hands with a towel.		
Step 10	Turn off the sink tap.		Hang up the washcloth to dry.			
Step 11	Wipe mouth with a towel					
Step 13	Twist the cap onto the toothpaste					
Step 14	Put toothpaste away.					