Communication App for Patients with Locked-in Syndrome

Introduction

- Locked-in Syndrome (LIS) is a rare neurological disorder resulting from brain damage.
- Patients with LIS retain cognitive functions like thinking or listening but are unable to do anything except move their eyes and blink.
- LIS has no specific treatment or cure, and it is extremely rare for patients to recover any significant motor functions.
- During my search to find a science fair project, I came across an article about a police officer named Richard Marsh, who suffered from Locked-in Syndrome and recovered after 4 months and 9 days of painful rehab. The article left a deep impact on me, and I was determined to provide a voice to LIS patients by creating an app that'll make a positive difference in their lives.
- In my research, I discovered that the primary tool LIS patients use to communicate is a Letter Board, although communicating using this can be slow and tedious.
- There are also a few companies offering communication devices for Locked-in Syndrome patients, however all these solutions require additional costly devices:
  - Neuro-Key which converts brain data into commands.
  - Eyegaze is an eye-controlled technology.
  - EyeControl detects voltage changes in the eye.

Engineering Goal / Framework

- **Engineering Goal:** To develop an app that uses a smartphone's front-facing camera to track the patient's eye blinks, enabling them to navigate through the app and select desired phrases to be read aloud by the phone.
- The app will have a simple user interface with a home page that contains six categories of the most useful phrases that LIS patients could use to communicate.
- LIS patients will be able to navigate through the categories by blinking their eyes and can then select a specific category by closing their eyes for more than one second to launch a list of phrases in that category.
- When a user selects a phrase in a category by closing their eyes for more than one second, the phrase is read aloud through the app.
- The list of phrases in each category can be navigated in a circular loop.
- Each category has a "Return to Home" function to go back to the home page.

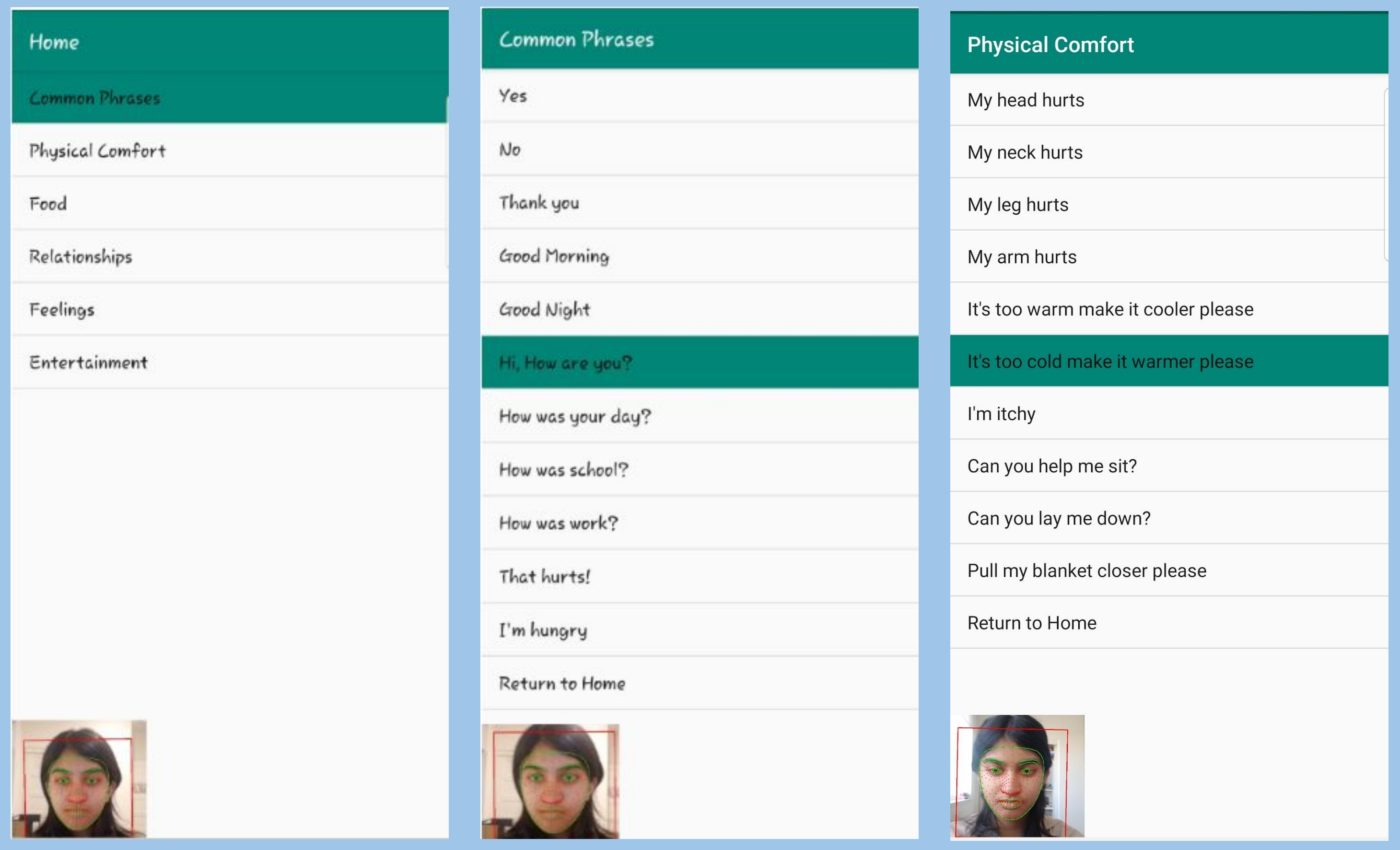
Procedure

1. Import all the essential Mediapipe libraries.
2. Identify the facial landmarks to detect blinks. The height of facial landmarks 386 and 373 on the eyelids and the height of stationary points 5 and 4 on the nose are used to calculate the eye height ratio, which is then compared against a threshold value to determine whether the eye had blinked.
3. Create a "Home" page category list and phrases using Android list view.
4. Program the "Return to Home" selection and circular loop navigation for lists.
5. Program the blinking function to navigate through the list and the phrase selection when the eye is closed for more than one second.
6. Use the Text-to-Speech class to convert the selected phrase to speech.

Testing Procedure

- Blink detection test to accurately scroll through the phrases/categories lists
  - Blink once and check if the app detected the blink for an eye height ratio of 0.8 and moved to the next category / phrase.
  - Run this test 50 times on different phrases and check results.
  - If the app does not detect 50 blinks accurately, modify eye height ratio to 0.5 and repeat test.
- Test to detect if the eyes were closed for a longer time to accurately select a phrase
  - Blink to any category or phrase and close eyes for more than 500 milliseconds.
  - Run this test 50 times and check results.
  - If the app does not detect the long eye closed 50 times, modify threshold to 1000 milliseconds to detect eyes closed and repeat test.
- Text-to-Speech accuracy test for all phrases
  - Blink to any phrase and close eyes for more than 1000 milliseconds.
  - Run this test for all 53 phrases and check if text to speech is accurate.
  - If the app does not accurately convert text to speech for all phrases, check code for any errors, and repeat test.

Screenshots of the App

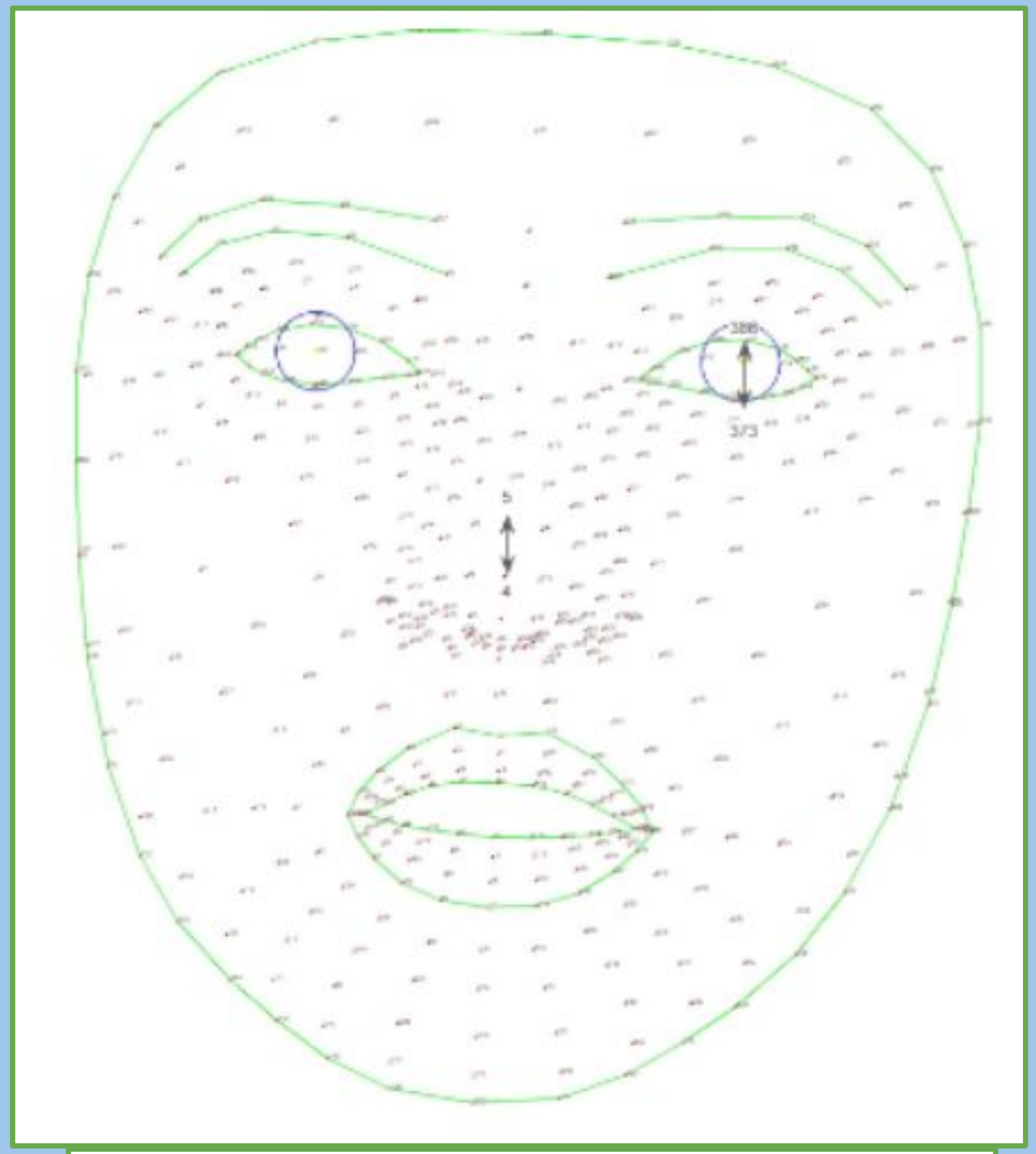


Home
Common Phrases
Physical Comfort
Food
Relationships
Feelings
Entertainment

Common Phrases
Yes
No
Thank you
Good Morning
Good Night
Hi, How are you?
How was your day?
How was school!?
How was work?
That hurts!
I'm hungry
Return to Home

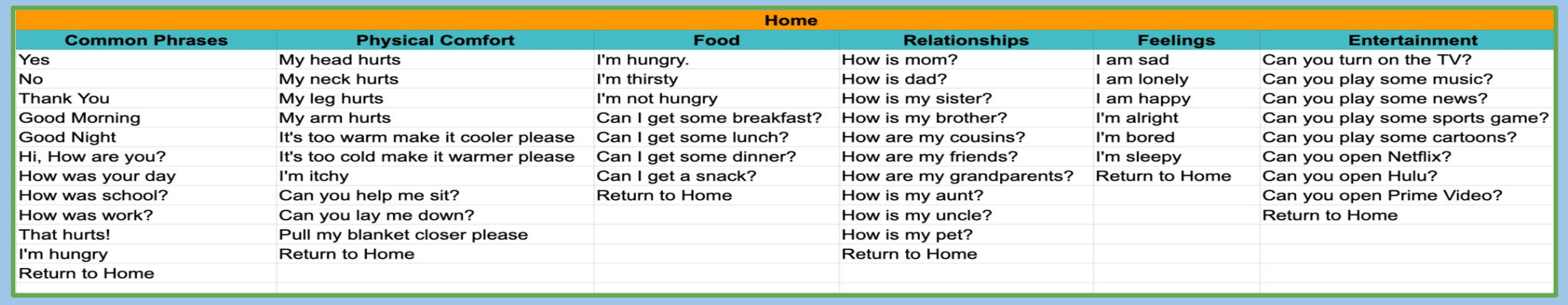
Physical Comfort
My head hurts
My neck hurts
My leg hurts
My arm hurts
It's too warm make it cooler please
It's too cold make it warmer please
I'm itchy
Can you help me sit?
Can you lay me down?
Pull my blanket closer please
Return to Home

Facial Landmarks



MediaPipe Face Mesh. Github. Jan 12, 2022. https://developers.google.com/mediapipe/solutions/vision/face_landmarker

Categories and Phrases list



Home					
Common Phrases	**Physical Comfort**	**Food**	**Relationships**	**Feelings**	**Entertainment**
Yes	My head hurts	I'm hungry.	How is mom?	I am sad	Can you turn on the TV?
No	My neck hurts	I'm thirsty	How is dad?	I am lonely	Can you play some music?
Thank You	My leg hurts	I'm not hungry	How is my sister?	I am happy	Can you play some news?
Good Morning	My arm hurts	Can I get some breakfast?	How is my brother?	I'm alright	Can you play some sports game?
Good Night	It's too warm make it cooler please	Can I get some lunch?	How are my cousins?	I'm bored	Can you play some cartoons?
Hi, How are you?	It's too cold make it warmer please	Can I get some dinner?	How are my friends?	I'm sleepy	Can you open Netflix?
How was your day	I'm itchy	Can I get a snack?	How are my grandparents?	Return to Home	Can you open Hulu?
How was school?	Can you help me sit?	Return to Home	How is my aunt?		Can you open Prime Video?
How was work?	Can you lay me down?		How is my uncle?		Return to Home
That hurts!	Pull my blanket closer please		How is my pet?		
I'm hungry	Return to Home		Return to Home		
Return to Home					

Results

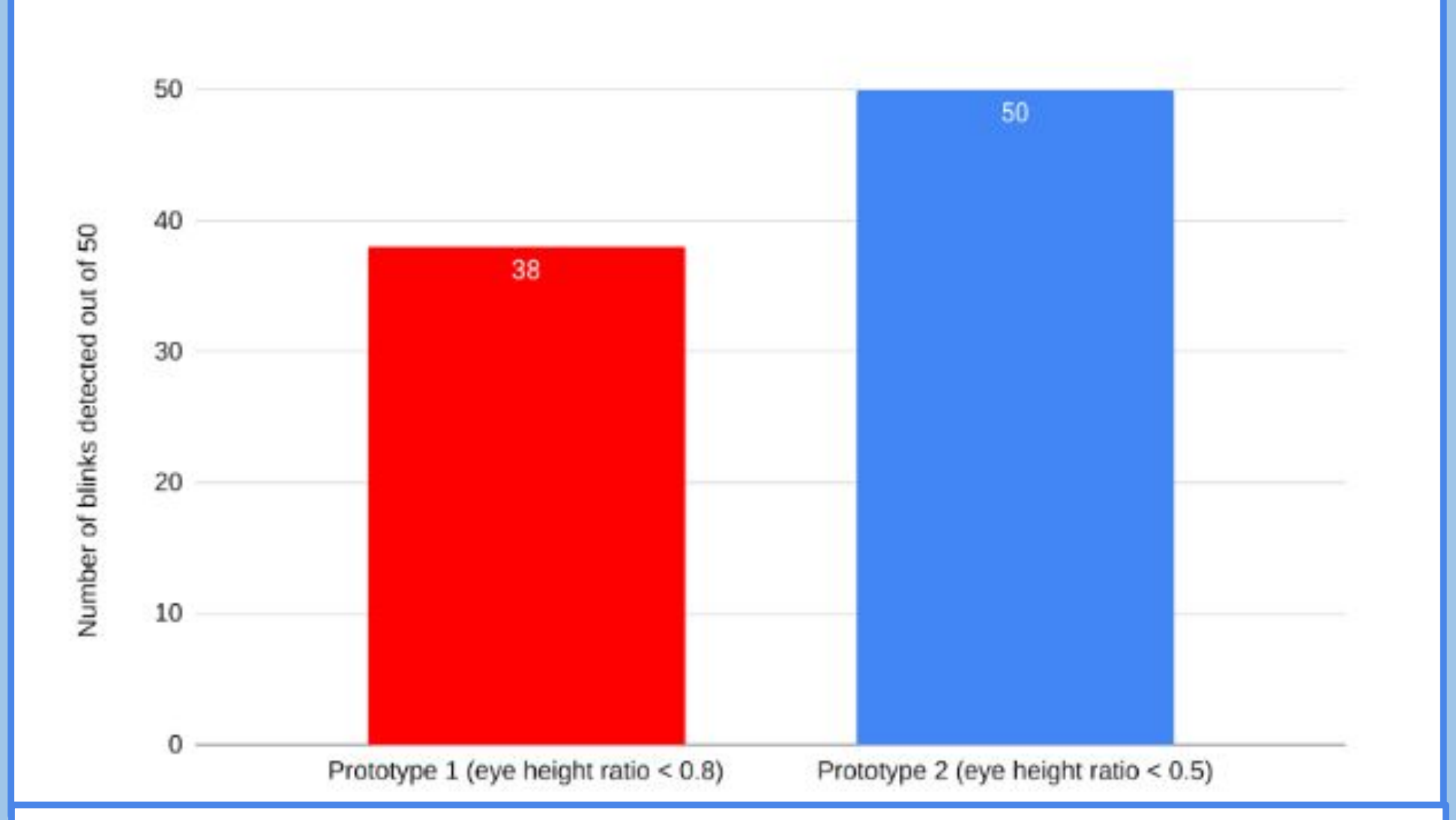


Chart 1: Blink Detection Test to Accurately Scroll Through the Phrases/Categories Lists

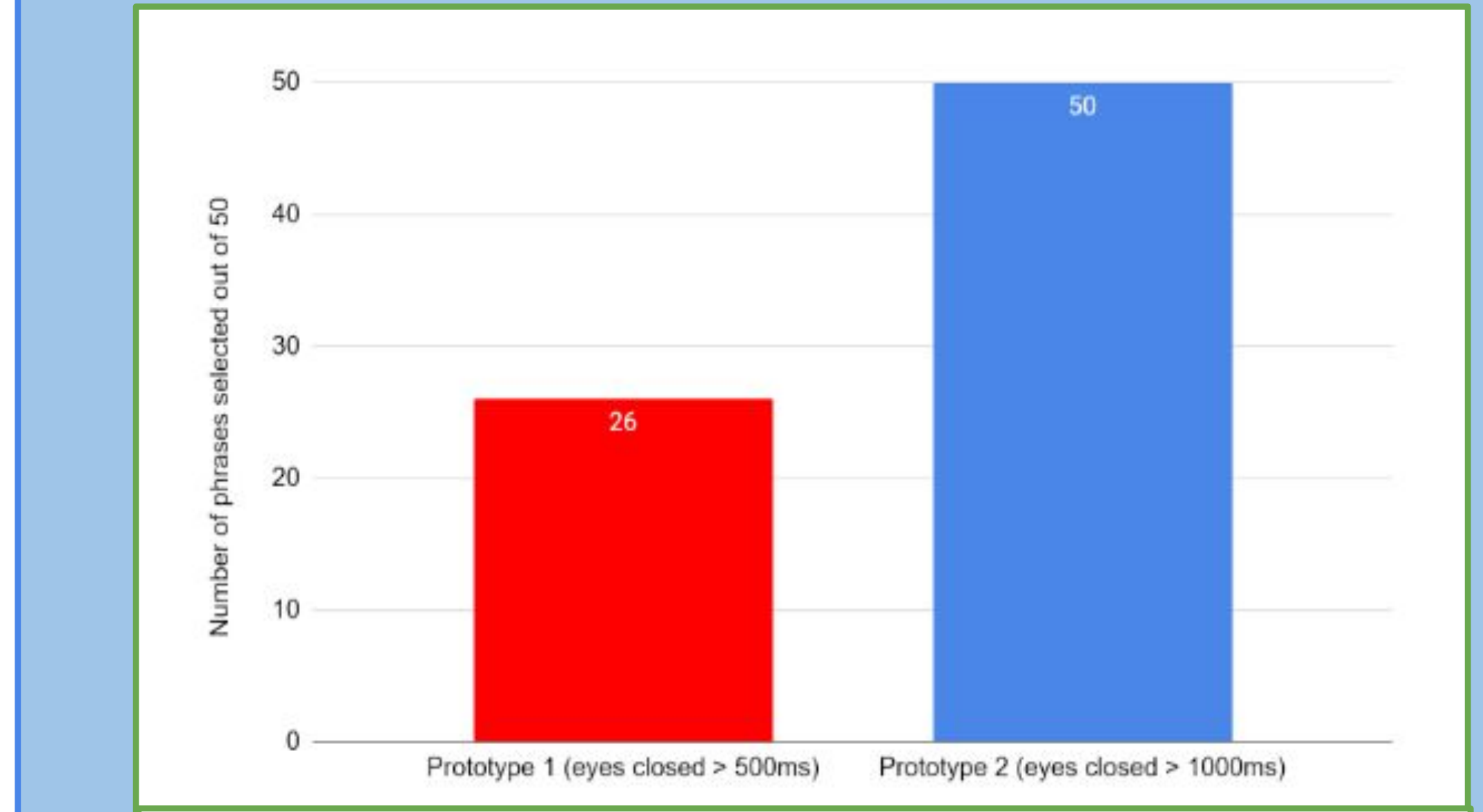


Chart 2: Test to Detect if the Eyes were closed for a longer time to accurately Select a Phrase

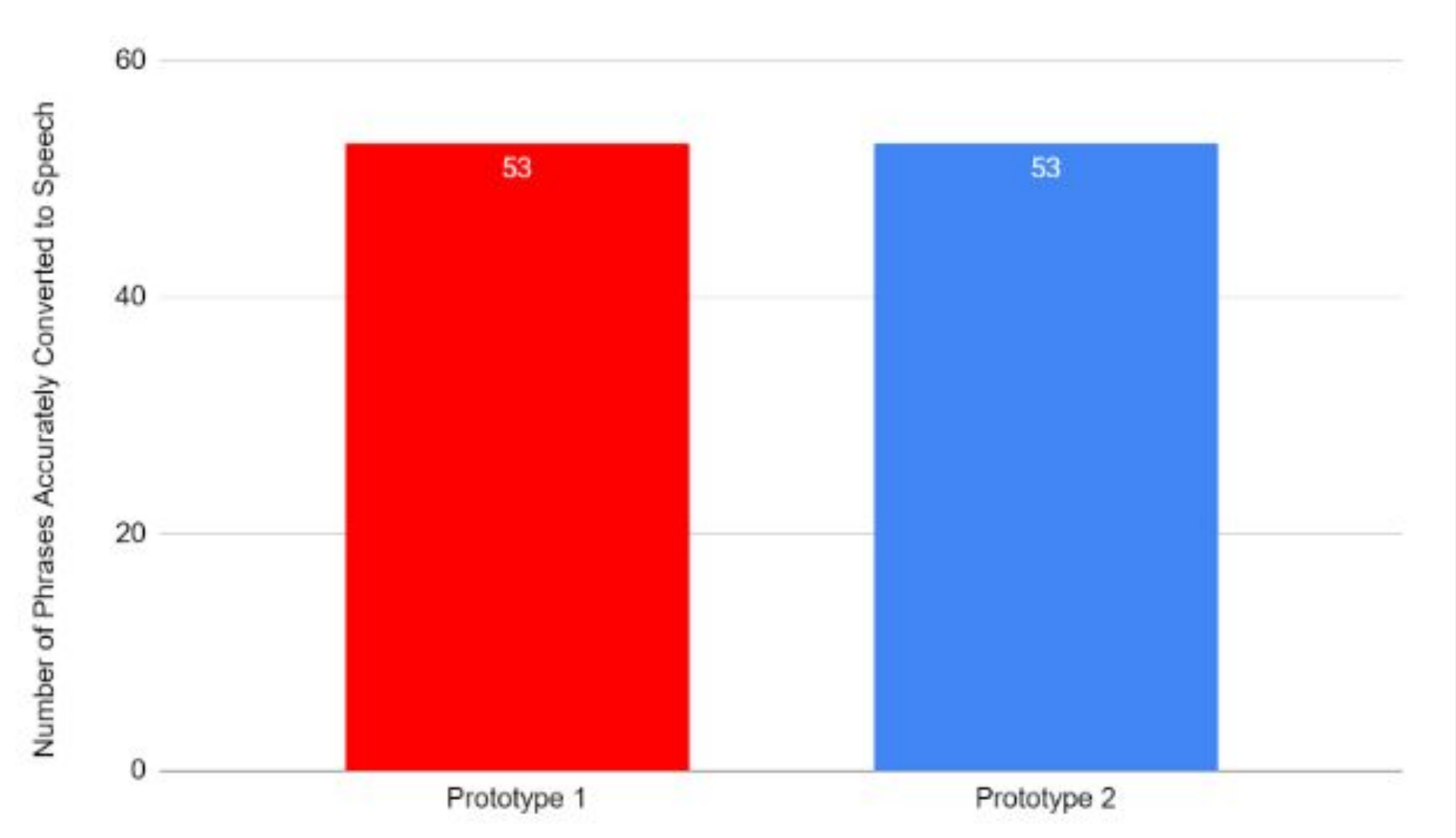
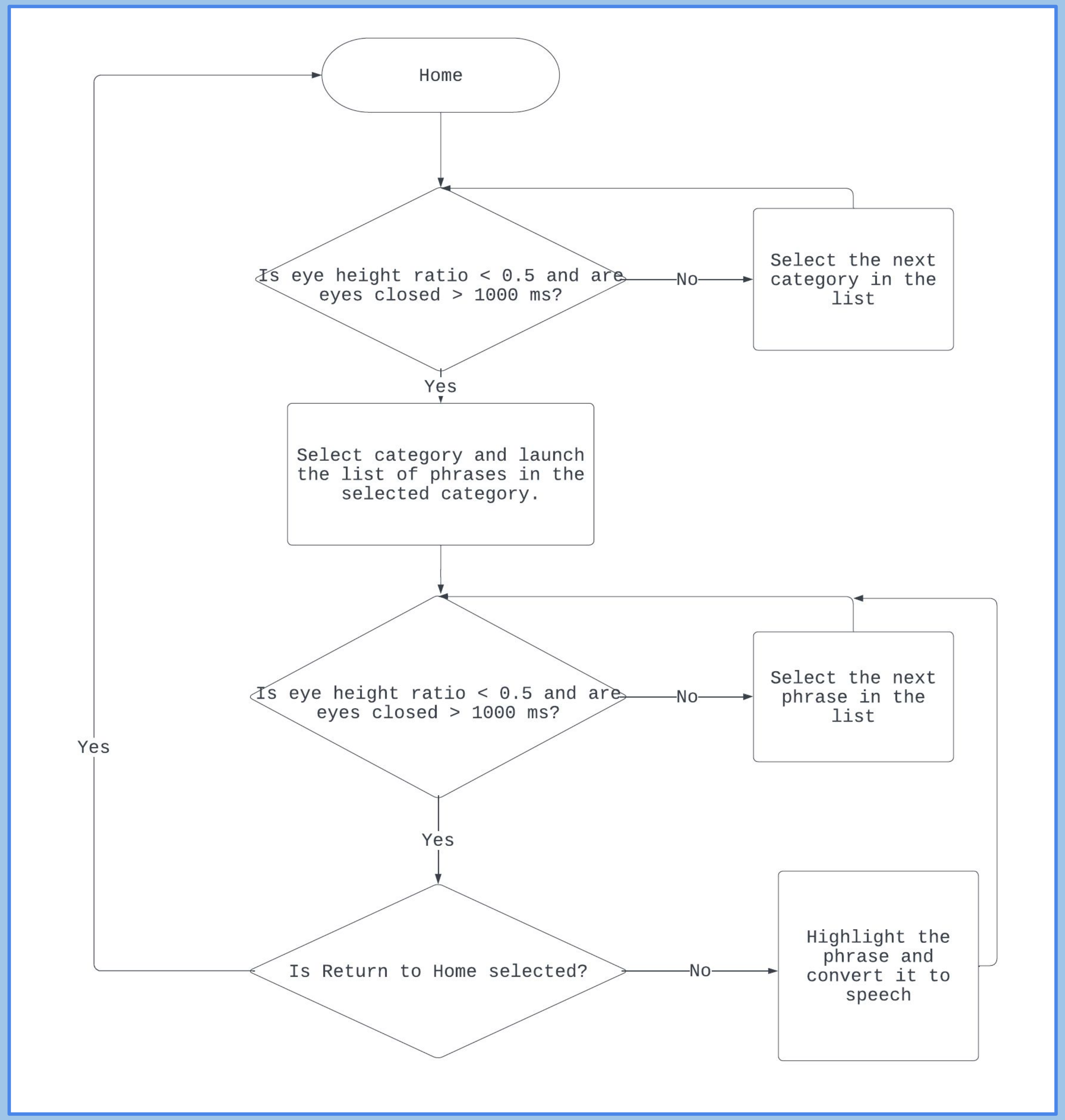


Chart 3: Text-to-Speech Accuracy Test for all Phrases

App Flowchart


Home
Is eye height ratio < 0.5 and are eyes closed > 1000 ms?
No
Select the next category in the list
Yes
Select category and launch the list of phrases in the selected category.
Is eye height ratio < 0.5 and are eyes closed > 1000 ms?
No
Select the next phrase in the list
Yes
Is Return to Home selected?
No
Highlight the phrase and convert it to speech
Yes

Results

- **Blink detection test to accurately scroll through the phrases/categories lists:** Prototype 1 with an eye height ratio of 0.8 detected only 38 out of 50 blinks, whereas Prototype 2 with an eye height ratio of 0.5 detected all 50 blinks, showing that the 0.5 ratio is more effective.
- **Test to detect if the eyes were closed for a longer time to accurately select a phrase:** Prototype 1 with a threshold of eyes closed time greater than 500 milliseconds, accurately selected only 26 out of 50 phrases, whereas Prototype 2 with a threshold greater than 1000 milliseconds successfully selected all 50 phrases, showing that the latter is more efficient.
- **Text-to-Speech accuracy test for all phrases:** Text-to-speech module accurately converted all the phrases to speech accurately.

  Prototype 2 of the app met my engineering goal of developing a free mobile app that will enable LIS patients to communicate by blinking their eyes.

Interpretation of Data / Discussion

- Prototype 2 of the app fulfilled the success criteria by:
  - Detecting 50 out of 50 blinks to scroll through the lists of phrases.
  - Detecting 50 out of 50 eyes closed for more than 1 second to select a phrase.
  - Converting all 53 of the phrases to speech.
- Improvements made from Prototype 1 to 2 were:
  - Changing the eye height ratio from 0.8 to 0.5 to detect blinking accurately.
  - Changing the eyes closed time for phrase selection from 500 milliseconds to 1000 milliseconds to detect eyes closed for more than one second accurately.
  - Fixed several bugs.
- The key learnings included designing and developing an Android app, testing, resolving any issues, and effectively managing time.
- A few companies have developed communication platforms for LIS patients that require expensive additional devices, whereas I have developed a free app that can be downloaded on any Android device.

Conclusion / Further Research

- I successfully developed a free Communication App for LIS patients that can run on any Android device with a front-facing camera.
- My final product exceeded my expectations for ease of use and it will significantly improve the quality of life of patients suffering from LIS by providing them with a voice and enabling them to communicate with those around them.
- Future enhancements for the app:
  - Develop an AI based letter board to add custom phrases.
  - Add user level customizations:
    - Changing the voice settings to male or female
    - Changing the voice output to a different language.
  - Develop an iOS app.

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All images and graphics were created by the researcher unless otherwise noted.