1 AIMS AND OBJECTIVES

1.1 AIMS

The aim of this project is to ascertain what haptic feedback is most applicable to an eye gaze control system, with a consideration of tetraplegic users. This study first aims to understand the current technology used for haptic feedback across the whole body, to then adopt their methods and technology to a facial haptic feedback system. The system that is being created should be capable of switching out different methods of applying haptic feedback to the user without a need for a complete switch of software. This will allow for experiments to be ran quickly without the need for a redesign of the system each time. The system will then be used to investigate the usability of the current configuration of the haptic feedback systems chosen. By evaluating these results from a series of participants, a general trend should emerge revealing a system with the most confidence in the assistance of completing a task.

1.2 OBJECTIVES

1.2.1 OBJECTIVE 1: GATHERING TECHNIQUES AND EXPERIMENTAL MODELS

The first aim of this study is to acquire a series of different methodologies from different studies. This will allow for an evaluation of the methods, and should allow for a suitable experiment to be developed from already proven ideas. Due to the lack of published studies on this topic in particular, it will be difficult to replicate an already established experiment.

1.2.2 OBJECTIVE 2: DEVELOPMENT OF THE FEEDBACK SYSTEM

The second aim of the study, is to develop and implement a haptic feedback system that is based on the works of (Sardinha, 2004). This aim can be broken down further; as seen below.

1.2.3 OBJECTIVE 2.1: ROS DEVELOPMENT

The beginning of this development process will begin with the ROS (Garage, 2007) development. This will attach to the software currently used in (Sardinha, 2004), by adding additional nodes to this system to handle the haptic feedback. These nodes will be able to process the information gathered by sensors and positional data from the prosthetic. This data can then be processed and turned into the relevant signals, leading to a simulated feedback occurring. By simulating the system first, it allows for the proof of the system to be correct.

1.2.4 OBJECTIVE 2.2: HARDWARE DEVELOPMENT

The exact configuration of the system will heavily depend on the literature review, and the experiment chosen for the task. However, the general idea will be to have a micro-controller (either an Arduino or a RaspberryPi), which will direct the feedback signals to the correct haptic device.

1.2.5 OBJECTIVE 2.3: REFINEMENT OF BOTH

I dont think this is needed?

1.2.6 Obective 3: Experiment and data collection

This objective will involve human participants using the system, and collecting both objective and subjective information from how the system was used. The specific dat collected will be decided by objective 1, and the relevant studies in this area.

2 Motivation and Need of study

With the ever advancing prosthetic technology in recent years, as seen in these studies for upper limb prosthesis's; (Clement, 2011) and (Clement, 2011), we see a clear lack of talk around the haptic feedback that these hands could benefit from. While (Clement, 2011) talks briefly on how users of prosthesis's are reluctant to adopt to a haptic feedback system, it clearly also states that the tasks performed by the participants see a positive effect when haptics are used. There is a lack of a comparable study when using eye gaze technology, therefore the assumption is there would also be a positive correlation when haptics are used within an eye-gaze system.

With a large increase of life expectancy (Chamberlain, 2015) of those with spinal cord injuries, the strain on the care services of any given country will increase with a correlation of this. By giving those with spinal cord injuries, in particular tetraplegic patients, the tools to take back some independence by themselves in day to day tasks, the strain can be lessened. On top of this, by giving patients these tools, the quality of life can be increased as seen in a study (Rigby, 2010). This shows the need for these systems to be developed. However, the need for this technology to be developed and it actually being used is a different story. When looking at upper-limb prosthetics, it is worth taking note that almost half of users do not use their prosthetic due to comfort and difficulty (Salminger, 2020). The argument could be made that due to the lack of other control schemes available for tetraplegic patients that this study is non-relevant; however it also shows that people will not engage in a system developed for them if it is too difficulty, uncomfortable or non-intuitive. Finding non-intrusive methods that can be quickly adjusted to needs with minimal need for adjustments is therefore a must during the development of these systems. This shows a clear need for haptics to be designed in a way that is user centric, and put near the forefront of development rather than being tacked on at the end.

When researching haptic feedback, most systems are usually either about entertainment, teleoperated systems or upper-limb prosthetics. The few studies which mention using both eeye-gaze and haptic feedback are either on a virtual level (Rantala, 2015), which while have some merit as a basis for further study, does not contain any data that could be used in a real world study. Or they are done by adding vibro-tactile feedback onto the glasses themselves, marketing more towards a "complete" solution as seen in (Kangas, 2014). This study however is a good starting point, as it shows a positive relation in real world tasks when the Google Glasses (Google, 2013). This is further agreed upon by a study done by (Rantala, 2020) where a series of studies done on the effects of vibro-tactile haptic feedback is reviewed with eye-gaze being the control scheme. All studies showed good promise of vibro-tactile being a good method to use, however none of the studies occured when using a prosthesis. While the results should be comparable, it is a strong motivator for this study to see if they correlate with the real world.

Nerve stimulating feedback has begun to be implemented into upper-limb and lower-limb prosthesis's as seen in (Kim, 2022). While the overall results show positive trends, it requires a unique solution for individual patients, if surgery is required it requires large amounts of resources dedicated to it, and the results are comparable to current non-invasive methods. While there is no doubt that nerve stimulation is the future, for the resources required to develop a competent solution, it is more viable to use non-invasive methods due the previous points.

- Aging population
- Lack of research into eye-gaze
- Invasive is still unsafe and non-mainstream
- Reducing cognitive load

3 Literature Review

This literature review will be broken down into 5 parts: While this study is aimed at eye-gaze technology, the amount of research done on upper and lower limb prosthetic feedback is far greater than that of its gaze-control counterpart. Comparisons will be drawn between the two, however it is worth noting that they may not translate perfectly.

1. Current methods used to evaluate haptic feedback
2. Popular trends in haptic feedback
3. Gaze Control with Haptic Feedback
4. Cognitive loads and reaction times
5. Usability of systems in the real world

3.1 Current methods used to evaluate haptic feedback

When trying to develop a suitable method to be able to evaluate the results that will be gathered by this study, it is important to focus on not just the results compared to a control group of no haptic feedback, but also on the overall user experience of the system. This is due to the problems outlined in (Salminger, 2020), where users will stop using a prosthetic if the system is deemed too complicated. To start with, there is a wide variety of different testing parameters for gauging how objectively successful an implementation of haptic feedback is, in a review study of trans-radial prosthesis's (Stephens-Fripp, 2018) there is no study which uses the same exact parameters. Some trends start to emerge however, for example in (Bark, 2010a) they use a method where the participant has to guess the rotation of the skin stretch applied to the forearm, giving a result in the amount of confidence in the accuracy of the application. This can be seen in more studies in the review also. While this is good for testing of an individual component, it is hard to translate into a complete system when tasked with real world activities. Something that is prevalent however, is the idea of convergence between the range of degrees the participant can accurately guess in, and the precision of the measurement. This was shown in the results to be consistent after convergence had been met, so while basing a study around this would not work due to differing haptic feedback methods aimed to be tested, by creating a simple convergence test beforehand, it allows for the system to be working in an optimal fashion.

3.2 Trends in Haptic Feedback

There is a multitude of haptic feedback devices out there, such as; Vibro-tactile (Alahakone, 2009), electro-tactile (Kourtesis, 2022), temperature (Peiris, 2017), skin stretch (Bark, 2010b) and mechano-tactile (Fan, 2008). All of these haptic feedback systems work when used by themselves for respective tasks. Temperature based haptic feedback while being incredibly accurate, has most use when used to judge temperature on the contact point of the prosthetic. While this could have a use case; it is not something that is required of this study. Therefore the main points of research will be focussed around the remaining systems listed here.

Vibro-tactile is one of the most heavily researched haptic feedback systems, and has been proven that users can tell differences in the frequency of the vibration (lost paper need to find again, it gives a much better idea of the frequency differences). This shows good promise for the low sensitivity needed for vibro-tactile to applied comfortably on the face. Vibro-tactile attached to glasses (Rantala, 2015) has good results, and could be easily extended to find out optimum placement.

Electro-tactile (lost papers, need to find again)

Temp (lost papers, need to find again)

3.3 Gaze Control with Haptic Feedback

3.4 Cognitive Loads and Reaction Times

3.5 Usability of Systems in the Real World

3.6 Page Setup

The paper size must be set to A4 (210x297 mm). The document margins must be the following:

- Top: 3,3 cm;
- Bottom: 4,2 cm;
- Left: 2,6 cm;
- Right: 2,6 cm.

It is advisable to keep all the given values because any text or material outside the aforementioned margins will not be printed.

3.7 First Section

This section must be in one column.

3.7.1 Title and Subtitle

Use the command *title* and follow the given structure in ”example.tex”. The title and subtitle must be with initial letters capitalized (titlecased). The separation between the title and subtitle is done by adding a colon ”:” just before the subtitle beginning. In the title or subtitle, words like ”is”, ”or”, ”then”, etc. should not be capitalized unless they are the first word of the title or subtitle. No formulas or special characters of any form or language are allowed in the title or subtitle.

3.7.2 Authors and Affiliations

Use the command *author* and follow the given structure in ”example.tex”. Please note that the name of each author must start with its first name.

3.7.3 Keywords

Use the command *keywords* and follow the given structure in ”example.tex”. Each paper must have at least one keyword. If more than one is specified, please use a comma as a separator. The sentence must end with a period.

3.7.4 Abstract

Use the command *abstract* and follow the given structure in ”example.tex”. Each paper must have an abstract up to 200 words. The sentence must end with a period.

3.8 Second Section

Files ”example.tex” and ”example.bib” show how to create a paper with a corresponding list of references.

This section must be in two columns.

Each column must be 7,5-centimeter wide with a column spacing of 0,8-centimeter.

The section text must be set to 10-point.

Section, subsection and sub-subsection first paragraph should not have the first line indent.

To remove the paragraph indentation (only necessary for the sections), use the command *noindent* before the paragraph first word.

If you use other style files (.sty) you MUST include them in the final manuscript zip file.

3.8.1 Section Titles

The heading of a section title should be in all-capitals.

Example: *section*{*FIRST TITLE*}

3.8.2 Subsection Titles

The heading of a subsection title must be with initial letters capitalized (titlecased).

Words like ”is”, ”or”, ”then”, etc. should not be capitalized unless they are the first word of the subsection title.

Example: $\backslash$*subsection*{*First Subtitle*}

3.8.3 Sub-Subsection Titles

The heading of a sub subsection title should be with initial letters capitalized (titlecased).

Words like ”is”, ”or”, ”then”, etc should not be capitalized unless they are the first word of the sub subsection title.

Example: $\backslash$*subsubsection*{*First Subsubtitle*}

3.8.4 Tables

Tables must appear inside the designated margins or they may span the two columns.

Tables in two columns must be positioned at the top or bottom of the page within the given margins. To span a table in two columns please add an asterisk (*) to the table *begin* and *end* command.

Example: $\backslash$*begin*{*table**}
$\backslash$*end*{*table**}

Tables should be centered and should always have a caption positioned above it. The font size to use is 9-point. No bold or italic font style should be used.

The final sentence of a caption should end with a period.

Table 1: This caption has one line so it is centered.

Example column 1	Example column 2
Example text 1	Example text 2

Table 2: This caption has more than one line so it has to be justified.

Example column 1	Example column 2
Example text 1	Example text 2

Please note that the word ”Table” is spelled out.

3.8.5 Figures

Please produce your figures electronically, and integrate them into your document and zip file.

Check that in line drawings, lines are not interrupted and have a constant width. Grids and details within the figures must be clearly readable and may not be written one on top of the other.

Figure resolution should be at least 300 dpi.

Figures must appear inside the designated margins or they may span the two columns.

Figures in two columns must be positioned at the top or bottom of the page within the given margins. To span a figure in two columns please add an asterisk (*) to the figure *begin* and *end* command.

Example: $\backslash$*begin*{*figure**}
$\backslash$*end*{*figure**}

Figures should be centered and should always have a caption positioned under it. The font size to use is 9-point. No bold or italic font style should be used.

Figure 1: This caption has one line so it is centered.

Figure 2: This caption has more than one line so it has to be justified.

The final sentence of a caption should end with a period.

Please note that the word ”Figure” is spelled out.

3.8.6 Equations

Equations should be placed on a separate line, numbered and centered.
The numbers accorded to equations should appear in consecutive order inside each section or within the contribution, with the number enclosed in brackets and justified to the right, starting with the number 1.

Example:

$$a = b + c \tag{1}$$

3.8.7 Algorithms and Listings

Algorithms and Listings captions should have font size 9-point, no bold or italic font style should be used and the final sentence of a caption should end with a period. The separator between the title of algorithms/listings and the name of the algorithm/listing must be a colon. Captions with one line should be centered and if it has more than one line it should be set to justified.

3.8.8 Program Code

Program listing or program commands in text should be set in typewriter form such as Courier New.

Example of a Computer Program in Pascal:

Data: this text
Result: how to write algorithm with LaTeX2e
initialization;
while *not at end of this document* **do**
    read current;
    if *understand* **then**
        go to next section;
        current section becomes this one;
    else
        go back to the beginning of current section;
    end
end

Algorithm 1: How to write algorithms.

```
Begin
    Writeln('Hello World!!');
End.
```

The text must be aligned to the left and in 9-point type.

3.8.9 Reference Text and Citations

References and citations should follow the APA (Author, date) System Convention (see the References section in the compiled manuscript). As example you may consider the citation (Smith, 1998). Besides that, all references should be cited in the text. No numbers with or without brackets should be used to list the references.

References should be set to 9-point. Citations should be 10-point font size.

You may check the structure of "example.bib" before constructing the references.

For more instructions about the references and citations usage please see the appropriate link at the conference website.

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5 CONCLUSIONS

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ACKNOWLEDGEMENTS

If any, should be placed before the references section without numbering. To do so please use the following command: *section*{ACKNOWLEDGEMENTS}

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APPENDIX

If any, the appendix should appear directly after the references without numbering, and not on a new page. To do so please use the following command: *section**{*APPENDIX*}