Robotic Hand Rehabilitation Device for Stroke Patients

DNB311 ID STUDIO 7

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Contents

Acknowledgments 2
Abstract 3
Section 1.0 4
1.1 Introduction 4
1.2 Literature Review 5
1.2.1 Strokes 5
1.2.2 Brain Injuries 5
1.2.3 Neuromuscular Disorder 5
1.2.4 Rehabilitation 5
1.2.5 Rehabilitative and Assistive Devices 6
1.2.5.1 Robotic Exoskeletons 6
1.2.5.2 Artificial Tendons 6
Section 2.0 7
2.1 Research 7
2.1.1 Methodology and method 7
2.2 Analysis 8
2.3 Findings 8
2.3.1 Survey 8
2.3.2 Interview 10
Section 3.0 11
3.1 Discussion 11
3.2 Design Implications 12
3.3 Conclusion 14
References 15
Appendix 17

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Abstract

The recovery process of stroke patients is highly dependent on the rehabilitation they receive. Various types of rehabilitative tools and devices are utilised in this process. Especially an area slowly being introduced in many forms in the use of robotic rehabilitation. This is an important area of research and focus, as there is a lack of resources available for adequate rehabilitation for stroke patients. The aims of this project and study were to understand the issues stroke patients have with hand rehabilitation and find solutions to these issues with the use of robotic rehabilitation. The study was conducted via interviews and online surveys to collect primary data on the experiences within rehabilitation. In the study, it was found that most people had issues with the rehabilitation and recovery of their hand functions and showing that there was a lack of engagement in the process. Further research suggested the rehabilitation process benefits from robotic devices aiding in the process of providing rehabilitation without the need for supervision. The study implies that robotic rehabilitation is the next step in rehabilitating patients post stroke. This provides design opportunities to be carried out to fill these areas of need.

Section 1.0

1.1 Introduction

The purpose of this research is to develop an understanding of the impacts of robotic rehabilitation of the hand, focusing on patients who have suffered a stroke. The aim is to identify areas within the rehabilitative process that pose a problem and have a potential opportunity for design intervention. This project will explore potential ways to improve hand rehabilitation management; using wearable technology to encourage patients to complete exercises and continue to take part in their rehabilitative process fully. Based on the research and findings, the project will be designing a device to function within a rehabilitation clinic to assist the regaining of hand functions and strength, that can also integrate well into the home in order to continue this rehabilitative process for as long as is needed.

This research report will look into existing robotic hand rehabilitation devices and will analyse data from primary sources. The research of existing devices and comparison with data found in this report from test subjects will help to highlight what is lacking in current designs and provide promising design opportunities.

This report will introduce literature that covers brain injury - specifically strokes - the following rehabilitation, and the use of robotic hand exoskeletons for upper limb movement, and how they assist in the process of regaining function for those affected by brain injuries. The following section will outline the methods and approaches taken to retrieve primary data, exploring the positive and negative outcomes of the modes of data collecting. This data will then be analysed in 2.2 of the report, then presented and explained in relation to the findings of the research. Section 3 of the report will lay out the discussion points, and the juxtaposition of the findings and the literature review, revealing new discoveries and areas that should be covered in relation to this topic. In the following design implications section, the designs will be informed by these discoveries and findings and will outline the direction they will need to go in to create the most accessible device possible. Finally, the report will conclude with a general summary, and acknowledgement of how the report's findings have informed the design of a robotic exoskeleton device, and what opportunities this report has opened up.

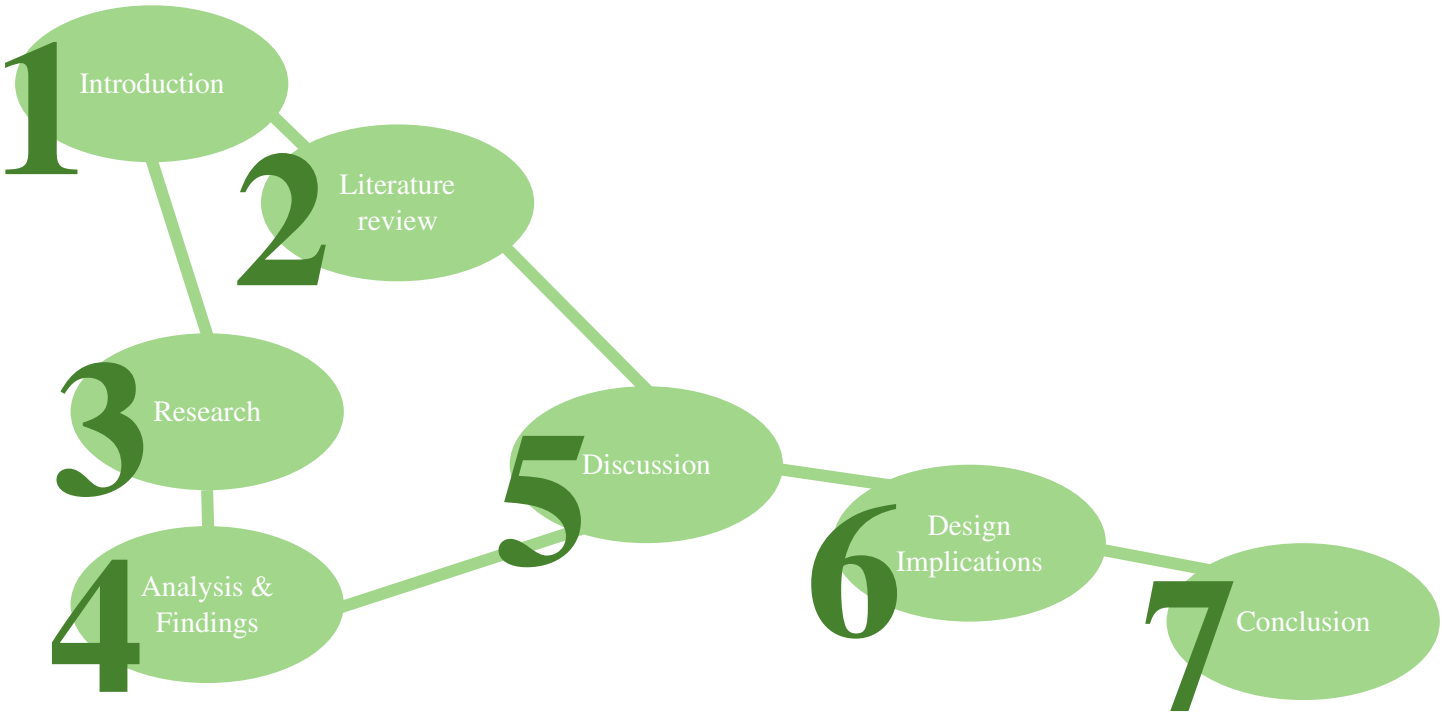


Figure 1: visual overall of report structure

1.2 Literature Review

There are various areas that robotic rehabilitation covers as it allows for the rehabilitation process to continue outside of the clinic while also providing assistance to those who suffer or have suffered from conditions such as Strokes, Brain injuries and neuromuscular disorders.

1.2.1 Strokes

In Australia, strokes are the second largest killer, just below coronary heart disease, and a major cause of disability. An article written in 2012 predicted that 0.5 million Australians were likely to suffer from a stroke at some point in their life. Strokes impact the flow of blood to areas of the brain either by a blockage or a bleed, this is detrimental as the brain requires a consistent supply of oxygen and other nutrients provided by a steady supply of blood to function. These differences in causes are the main two types of strokes ischemic, blockages, and haemorrhagic, bleeds, with ischemic being the most common form of a stroke to occur. (Gomes & Wachsman, 2013)

The impact on blood supply causes part of the brain to die off, this could be up to 1.9 million cells per minute. ("What is a stroke?", 2022) A stroke can cause various damage to the brain and the person's body, impacting emotions, brain activity and memory, muscle weakness and issues with speaking, hearing or vision.

1.2.2 Brain Injuries

Traumatic brain injuries (TBI) can present in various forms from a minor changing the cognitive state and consciousness or enlarged issues of comatose or death. Treatment varies from intensive surgery or cognitive therapy. (Galgano et al., 2017) Around 69 million people per year suffer a Traumatic brain injury, with only 8% being severe and 81% being mild. However, the consequences that these injuries have is devastating. The executive function impairments that result from traumatic brain injuries, greatly impact the independence of people in their day-to-day life. (Ertas-Spantgar et al., 2022)

1.2.3 Neuromuscular Disorder

Neuromuscular disorders (NMD) is an umbrella term that spreads over various conditions that affect the function and control of muscles. A neuromuscular disorder affects nerves that control voluntary muscles. ("Neuromuscular disorders | Neuroscience nursing | Royal College of Nursing", 2022) Rehabilitation is integral to managing life with a neuromuscular disorder, due to the diversity within NMD various assessments along with performance and fatigue levels are all monitored to determine the best form of rehabilitation. (Demir, 2017) the aim of the rehabilitation of NMD is to utilise various techniques, such as assistive devices, to help improve the function of muscles and to help provide a level of independence.

1.2.4 Rehabilitation

Post Stroke it is recommended in a perfect situation that patients receive 3 hours of rehabilitation every day for the best recovery, unfortunately, patients can receive as little as an average of 37 minutes per day or less than 25% of this recommended amount. (Foley et al., 2012) This is due to the lack of space in stroke wards and the inability for specialised rehabilitation from Occupational Therapists (OTs) to utilise the neuroplasticity to retrain the areas that have been damaged. The amount of therapy that patients can receive allow varies due to the severity of their stroke or to the amount of funding they receive and care they need, for if they receive funding and need more care it'll go towards other forms of carers. However, if someone does not have funding, they may not be able to afford an extensive amount of rehab that would aid in their recovery. Alongside this there are various characteristics and factors that can affect the rehabilitation of results post stroke, these being age and severity of stroke as an example. Rehabilitation is often driven by the specialists available at the time rehabilitation is needed, rather than what is required from a clinical standpoint. Unfortunately, coupled with a lack of research into the need for Stoke rehabilitation and putting it into practice affects the recovery of patients. This is a key issue in the process of rehabilitation, especially with the window of rehabilitative restoration

varying greatly between stroke cases and severity levels. Stroke rehabilitation especially is far from the "one size fits all" type process, with care and therapy needing to be catered to each individual depending on the variable factors of what was most affected. (Cramer et al., 2017) Furthering this the days between stroke and starting rehabilitation can have a dramatic effect upon the outcome of regaining function. Keeping in mind that while a delay in rehabilitation can cause a reduction in an individual's regaining of function, aggressive rehabilitation can also be detrimental to a patient's recovery. Quicker and more accessible Rehabilitation services post stroke can greatly improve the functions regained and the amount of time spent in rehabilitation for the varying levels of stroke severity. (Maulden et al., 2005)

1.2.5 Rehabilitative and Assistive Devices

Current rehabilitation devices focus on various points of use but mainly focusing in on pinching functions or grasping. As post stroke, the control and strength of the hand are greatly affected and are difficult to regain completely. The aim of such devices is to improve the extension and flexion of finger movement. Robotic rehabilitation has proven to be greatly effective as it proves services for high repetition, dosage and intensity, and also helps to reduce the burden on manual rehabilitation services.

However, while there are benefits to at home rehabilitative devices there are risks that follow, such as malalignment causing incorrect and abnormal movements, this can cause irreparable damage and slow the recovery process by adding extra complications.

Of the robotic rehabilitative devices out there and growing, there are two main areas of focus on developing rehabilitative and assistive devices for post stroke rehabilitation, being exoskeleton gloves and artificial tendons. Both provide similar services in regaining hand movement but approach it in different ways.

1.2.5.1 Robotic Exoskeletons

Robotic hand exoskeletons are a type of wearable technology designed to improve the movement and functionality of the fingers and hands, by improving completing the full range of movement (ROM) in an impaired hand. (du Plessis et al., 2021) Exoskeleton devices aid in the movement of the fingers by assisting the finger to complete their full range of movement for the desired task. The mechanical structure of the exoskeleton can be completed in various forms with current concepts and products utilising pneumatic systems, hydraulics, or electric motors.

The variety in the applicable mechanical structures depends on the use and ability to utilise the device in certain areas. While also limiting the ability for certain levels of clinical practice and adjustment.

Exoskeletons fit over the hand in a similar way to orthosis, both providing safety and support. With the extra power that an exoskeleton has can aid in more severe hand rehabilitation, since each finger can be controlled, and each joint is supported with an overarching structure.

1.2.5.2 Artificial Tendons

Artificial tendons are a type of wearable technology that utilises cords and electric motors to pull the fingers closed to regain the function of the hand. This form of a wearable device is aimed more for less severe cases and injuries, being an easier rehabilitation path. However, artificial tendons are still extremely useful in the extension and flexion of the hand. A higher level of design and customisation is required for these types of devices to ensure a proper fit and ensure correct alignment with the robotic system.

The literature review explored the cause of needing rehabilitation, strokes, brain injuries and neuromuscular disorders. While also establishing an understanding of robotic rehabilitation devices and the main ways they are carried out. From here this carries into the primary research and where the correlation between firsthand rehabilitation and those who carry out the therapy is to understand what works in a real work situation.

Section 2.0

2.1 Research

The study conducted looked into the area of rehabilitation and robotics in the process of rehabilitating the hand post stroke. This study needs to be conducted to get an experiential understanding of how hand rehabilitation within stroke rehabilitation is managed and dealt with. And to understand the areas that require improvements and how a robotic rehabilitation device can aid in the improvement of these areas. It was recommended through the research into stroke patient cognitive abilities post stroke to utilise qualitative style questions with the option of quantitative short response. As people who have suffered a stroke or other brain injuries do not always have the ability to formulate written answers, especially depending on the duration of time since their stroke of TBI.

Some errors seem to have appeared in the survey results, this could be due to the way in which the survey was spread, as it was spread through online platforms meaning some data was pulled internationally. As well as the lack of classification of the term rehabilitation, specifically whether it pertained to in hospital and out of hospital treatment. Other points that could skew the data are the lack of diversity in responses being six stroke patients, one still in rehabilitation, and one participant who had a traumatic brain injury, while this has provided extra information it limits the accuracy and depth needed to accurately analyse the data.

2.1.1 Methodology and method

Desktop research was conducted initially using academic literature and journals to gain an understanding of strokes, brain injuries and neuromuscular conditions, and also the world of robotic rehabilitation. The research included information into what would be applicable in terms of the form to collect research and primary data collection with stroke patients.

A survey was conducted for the potential end users of the design, these users mainly being stroke patients, but also including brain injuries and neuromuscular conditions. As they can provide firsthand experiences on the rehabilitation journey. The survey consisted of 17 questions, 12 were qualitative and 5 were quantitative. I was able to receive 7 responses to my survey as people find talking about their stroke or brain injuries private and treat them as a sensitive topic and I respect those people's decisions to not take part. The choice to utilise a survey rather than an interview or other form of research was to allow people who may still be recovering to take their time to complete the survey and to remove the stress and pressure. While also removing any contact with them as these people are in a higher risk category for COVID-19, and other illnesses, and so the least amount of contact with them was the best option.

However, when it came to receiving information from an expert in stroke rehabilitation, I conducted a 20-minute semi-structured interview over the phone with ‘My Rehab Team’. We discussed their knowledge of the rehabilitation process. They provided invaluable information on how stroke patients and their rehabilitation are carried out and the process for the length of rehabilitation. Once again as this person comes into a various amount of people who are within the high-risk category for COVID-19, and other illnesses, it was advised that either a virtual interview or phone call would be the best way to carry out the interview and the quickest way to receive information.

2.2 Analysis

There were two methods utilised to analyse the primary data that was received through two processes. The first was the survey which contained both numerical based questions and short and long responses, so both methods were required to ensure that the common and more accurate themes and data were pulled from the responses.

Secondly, for the interview, this was all word based so it was important to analyse the themes found within as this was an expert in this field, the knowledge provided was a high level and held value points to discuss.

Within the analyse of the survey questions, for the numerical-based scale question Google forms automatically converts this quantitative data into graphs that are easily understood and convey the information clearly. For the short and long response questions in the survey, a thematic analysis was undertaken. The thematic analysis for the responses in the survey were not as detailed as the responses were short but all highlighted the key point of the data.

The analyse of the interview also required thematic analysis to ensure clear concise concepts and information was being pulled out. This analysis of the transcript creates the data that can be translated into graphs, tables or other useful representations of the data.

2.3 Findings

The survey and interview introduced interesting data that suggest various issues in the rehabilitation process, but especially upon the rehabilitation of their hands. The survey and interview linked to each other and showed potential issues.

2.3.1 Survey

The results from the survey data showed that patients post stroke, or a traumatic brain injury (TBI) did not receive consistent levels and time of rehabilitation, as seen in figure 2. There was data excluded within the survey as it would have skewed the data, see appendix 1 and 1.1 for full data.

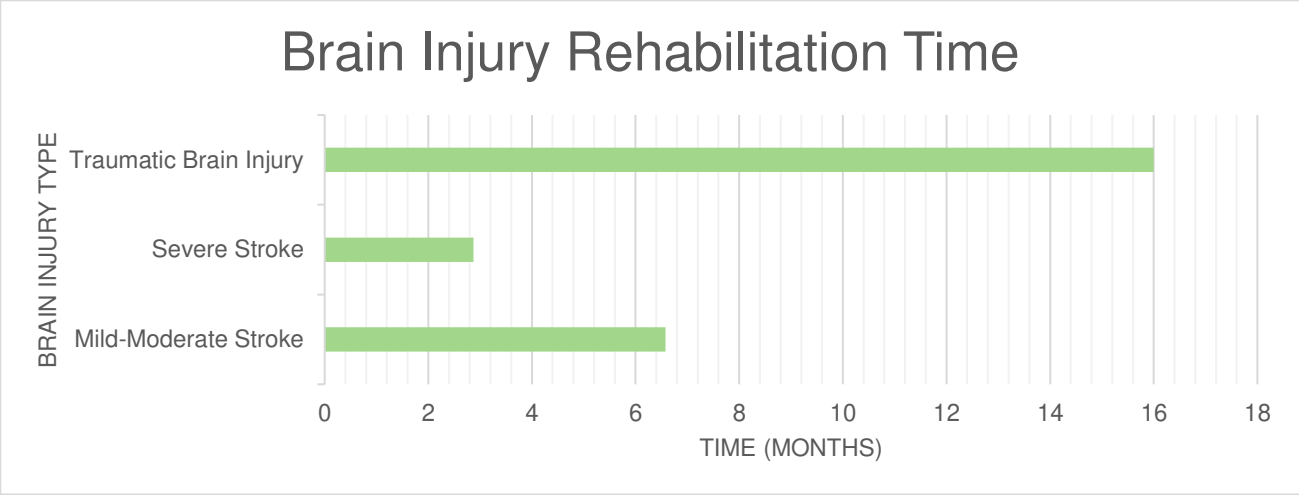


Figure 2 – average length of time patients spent in rehabilitation, explore appendix 1/1.1 for further data

This was followed by a vast variation in the amount of time spent with a rehabilitation specialist to help in the recovery, figure 3 (over the page). This data indicates the dissatisfaction that those who require high levels of rehabilitation to regain functions and mobility that are needed to return to their new standard of a normal life.

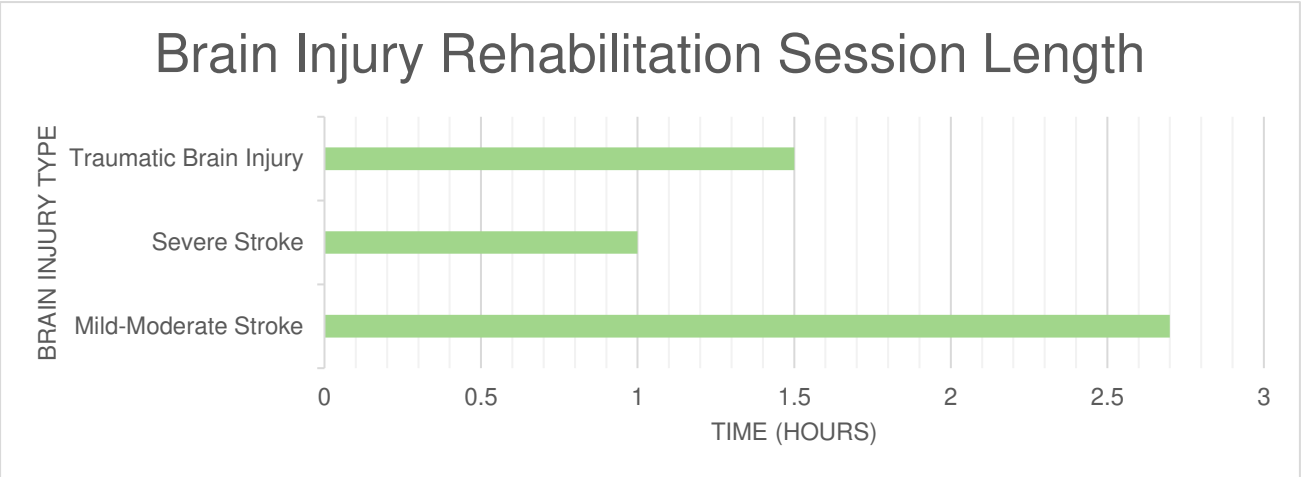


Figure 3 – average lengths of time each patient had per session, explore appendix 2/ 2.1 for further data

The participants of the survey stated that they did not feel they were adequately looked after in the rehabilitation process. With their expected goals and desired outcomes not being met. The data revealed an interesting split in the satisfaction with the rehabilitative device. With 42% of participants saying they did not find them completely useful, however, the other 68% found them imperative to their rehabilitation process. The participants shared that they did not find rehabilitation as engaging and looked for encouragement and feedback during the process as they needed an incentive.

The survey showed the lack of management of hand rehabilitation, as 86% did not feel they were managed well enough. Stating that their hands were not a key focus of the rehabilitation process, with their legs, balance and walking, being the main thing worked on in their sessions. Furthering, most of the participants stated they would have been interested in a wearable device that helped them to rehabilitate their hand functions, as seen in figure 4. As a majority stated they found the current devices and tools to be useful in rehabilitating but still has room for improvement. Suggesting the current devices and tools could be improved in the areas of dexterity and range of movement, use in different demographics, strength and mobility, and an overall emphasis on other movement types.

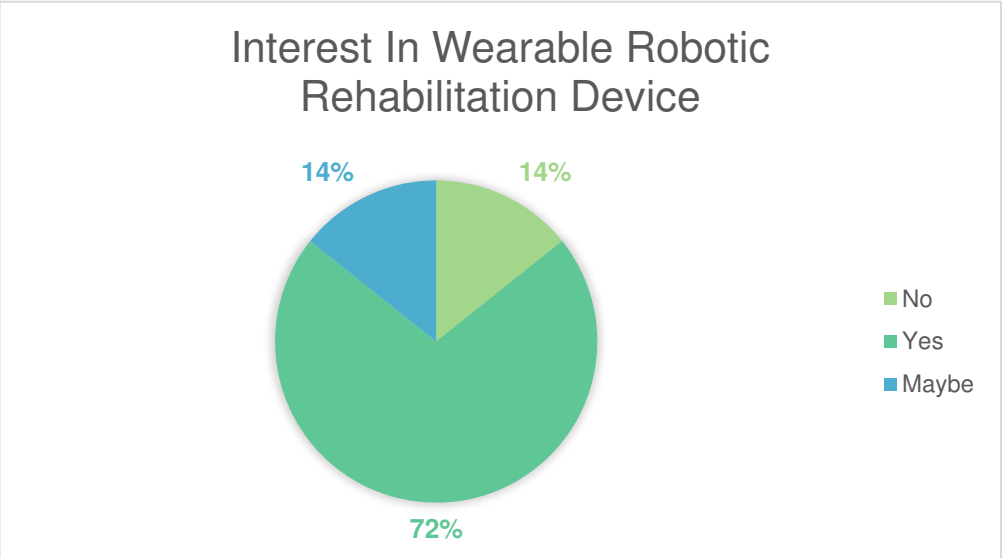


Figure 4 – graphical view of answers from survey on interest in robotics in rehabilitation

2.3.2 Interview

The result from the interview with an Occupational therapist that works with stroke patients at 'My Rehab Team', brought a new point of view to add to the people who conducted the survey. She stated that they usually provide patients with an hour's worth of rehabilitation in each session. She stated that this time can be affected due to the amount of funding that a patient receives or if they are paying for treatment themselves. The price of sessions changes depending on the length to reduce costs for people that will have less time with a therapist. She also stated the issues people have accessing rehabilitation stem from the funding and the demographic of those having strokes. As she doesn't often see the older population in the rehabilitation system, even though this is usually the demographic that suffers the most from strokes, due to the funding as they will have to cover other things, such as carers, nursing homes and other needs.

She stated that in the rehabilitation process that the patients will have a goal to reach in terms of function. As generalised rehabilitation does not work especially when it comes to dealing with neurological conditions as these are unique markers for rehabilitation needs. Professor Gavin Williams was a key person she mentioned in terms of this, as he has studied the training of stroke patients in the gym for running and how that does not help them to walk, an interesting connection that she pointed out.

The lady from 'My Rehab Team' has an interest in robotic rehabilitation and gave her standpoint on the issues with robotics, especially exoskeletons. She stated that most current devices don't train for actions, they only train movements but through research, especially conducted by Prof. Gavin Williams, training a joint to move does not carry across into daily use benefit. From this, she stated that an upper limb device could focus on action functions such as grasp and release, and the pincer grip, as these are commonly used functions in daily life. She continued to say that it is important that the device has a clear purpose such as aiding in a supportive function for severe weakness.

From the survey and interview, it is clear how the view of the patient receives rehabilitation and the person providing rehabilitation understands the process. From these findings will be discussed the gaps in the research from the literature review and the primary research to understand how it correlates.

Section 3.0

3.1 Discussion

Strokes and traumatic brain injuries greatly impact the abilities of those affected throughout various functions. Comparing the data and research collected via the survey and interview conducted and included in the literature review provided information that allowed for gaps to present themselves. These gaps include the lack of access to rehabilitation services, the engagement in the rehabilitation process and the satisfaction in the outcome of the functions regained during the rehabilitation process.

The literature pointed towards issues with the rehabilitation system with patients not receiving enough access to rehabilitative services, this was confirmed with the interview both recognising that the funding or lack thereof has issues in allowing patients to receive the amount of time they require to achieve the best in regaining functions. Following this research suggested the gaps with patients being provided with the complete services require as there is a lack of research in the area of stroke rehabilitation, and a lack of stroke unit availability to aid in immediate rehabilitation, found to be key in the process of regaining functions. The participants of the survey felt this lack of resources with them having a low satisfaction of the rehabilitation process as they felt they still have issues that were not touched on or discussed in rehabilitation.

There was not, much information that was available in the area of engagement in rehabilitation that was able to be provided in the literature review; however, the survey showed that there is a lack of engagement, with the interview confirming this as rehabilitation, has the highest level of success when patients are engaged. Unfortunately, with limited access, people are left to their own devices to complete their own rehabilitation at home without guidance, help and encouragement. While the patients of rehabilitation were comfortable in completing their rehabilitation at home, however, they lacked the engagement and missed the feedback and encouragement they receive while with a specialist.

These all helped to identify the gaps in the research and current practices, revealing areas that patients feel need improvements, areas that would aid in the specialist providing the rehabilitations, and overall improving the outcome of those who need to regain their functions post stroke or traumatic brain injury. These helped to inform the opportunities for design.

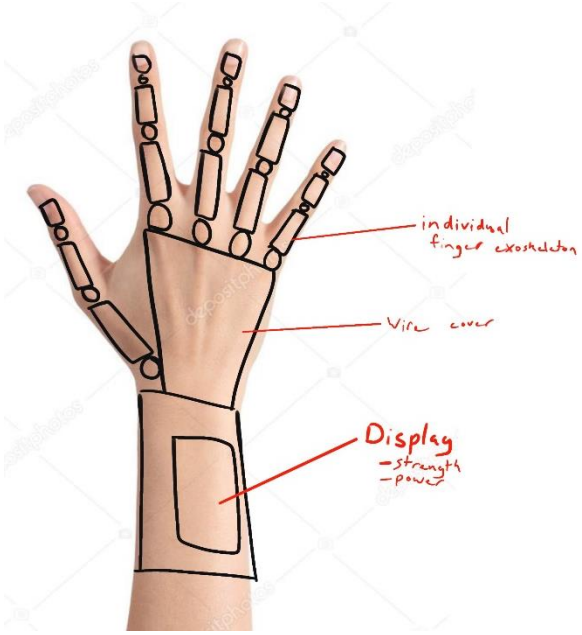
3.2 Design Implications

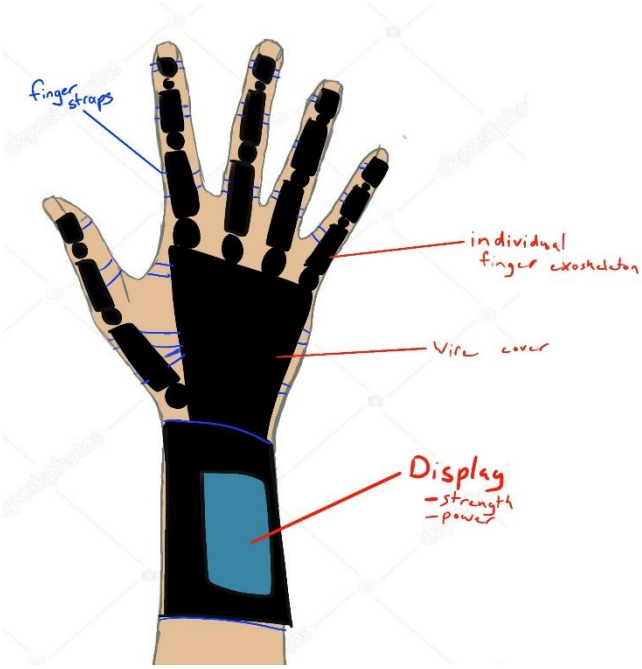
The rehabilitation of stroke patients provides various opportunities for design intervention. The research has revealed key areas that need to be designed for, and these gaps have created great opportunities for design intervention to help support the rehabilitation system. The research collected the problems of rehabilitation satisfaction, lack of access and time, and overstrain on an unprepared system. Through the process of research conducted it was revealed that rehabilitation at home would benefit the strained system by allowing for people to reduce the amount of time needing to be spent with a specialist. This would also benefit the patient as they would be getting adequate rehabilitation time. However, this does not come without its issues as patients also desired engagement during the process this usually came in the form of feedback or positive reinforcement from the specialist. Balancing the design implications of an at home and engaging rehabilitation is the task at hand.

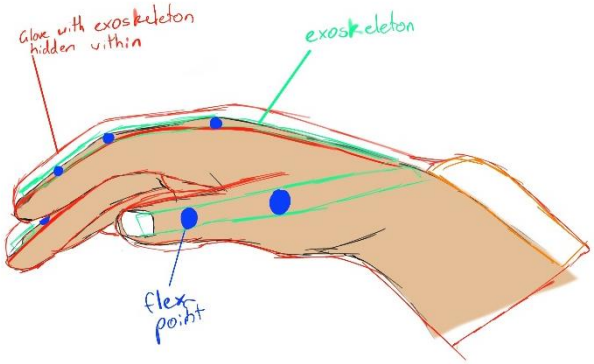
Robotic rehabilitation devices are not new to the world of rehabilitation, various other devices exist to aid in training and regaining function for other purposes. A device that could aid in the process of rehabilitation with the power of robotics would help the patient's strength and retrain the affected hand to perform various functions again. As it was encouraged during the interview conducted with the rehabilitation specialist that a robotic rehabilitation device should aid in developing functions, such as grasp and release or pincer grip, and not just move the hand, as this does not correlate with regaining function. Upon designing a device for a patient to use independently there is a chance of mal alignment of the device causing improper movements that can cause further damage, delaying the overall recovery process. This should be avoided as a rehabilitation device of this manner is to create a device to help regain function.

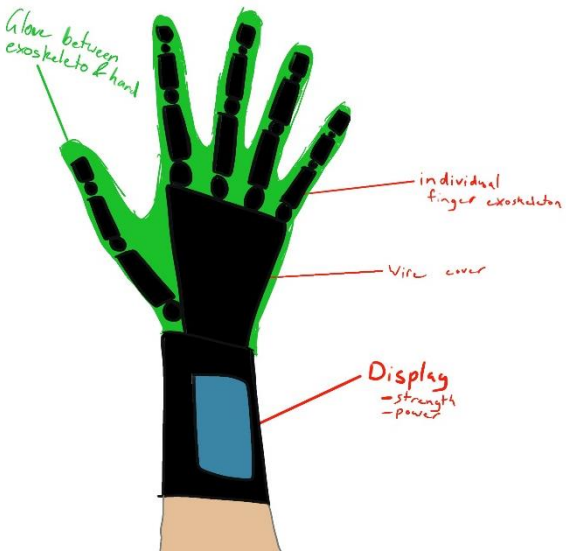
The device also needs to be engaging this can be carried out through interactive games built into the device that practices the same functions that the device would be training. This way the device can aid in rehabilitation in a real-world action when doing the task that requires it and also in a way that can aid in an engaging form of rehabilitation.

A design for a rehabilitative device also needs to ensure key aspects in the useability and functionality of the device. Such as the ability for cleaning, as the device will be worn for extended periods and will collect skin and sweat along with other dirt collected, other considerations should include the ease of storage when not in use and the ability for the device's treatment to be adjusted over time.









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DNB311 ID Studio 7

3.3 Conclusion

In conclusion, the aim of this report was to collect and analyse various source of information, from secondary sources, through journals and articles and convey them in the literature review and compare that information and compare the primary data collected through surveys and interview to find the gaps in the research. Unfortunately, primary data was hard to come by and retrieve as many people agreed to complete it or agreed to pass it on, however there was a low level of completed surveys. This is not a shock as the topic of stroke or other brain injuries are sensitive topics and can be hard to talk about especially depending on the impact it has had on their life and lives of others around them.

The purpose of this study and report was to understand how a robotic rehabilitation device could fit into the rehabilitation system and aid in the process of regaining functions for stroke patients or other brain injury patients that require this type of rehabilitation. The report covered existing rehabilitation devices that use robotics to help aid in regaining hand functions and analysed what worked and what does not work within these systems. This brought the options of device applications down to motorised devices in forms of exoskeletons or artificial tendons, with the form of exoskeletons becoming the clear option as there is limited risks that could affect the user's recovery and ability to regain functions.

Primary data of people's experiences was used further for this conclusion, as their answers showed the gaps in research of what they felt was lacking. This was also furthered by the rehabilitation specialist suggestions in positives and negatives of the rehabilitation system and current devices used for rehabilitative needs. This research data was utilised to provide the design implications and areas that can be further used to develop a realised functional device. With further development a device of that successfully aids in regaining function without the need for constant supervision, and also provide engagement in various forms.

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Appendix

1 – raw data for figure 1

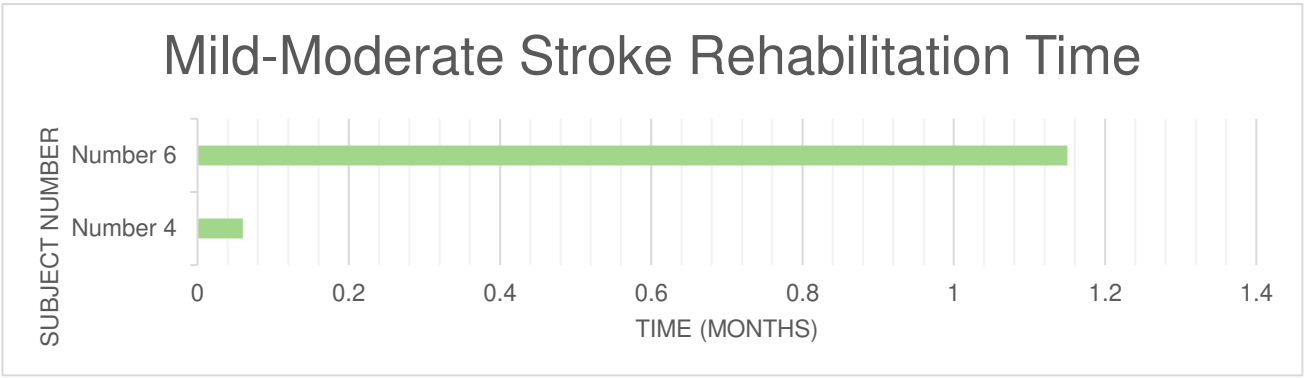
Hand Rehabilitation Post-Stroke - Survey Findings				
Survey Subject Number:	Test Subject Email:	Severity	Time in Rehab (Months)	Notes:
1	sunflowercircle1@aol.com	Severe	6	
2	rmhesom@gmail.com	Severe	1.61	
3	annev308@gmail.com	TBI	16	
4	pevans041@gmail.com	Mild-Moderate	0.06	
5	camerondb05@gmail.com	Severe	12	
6	airbornemedic8606@icloud.com	Mild-Moderate	1.15	
7	edavidlu@gmail.com	Severe	1	Data not used in averaged due to being an indefinite answer (ongoing treatment)

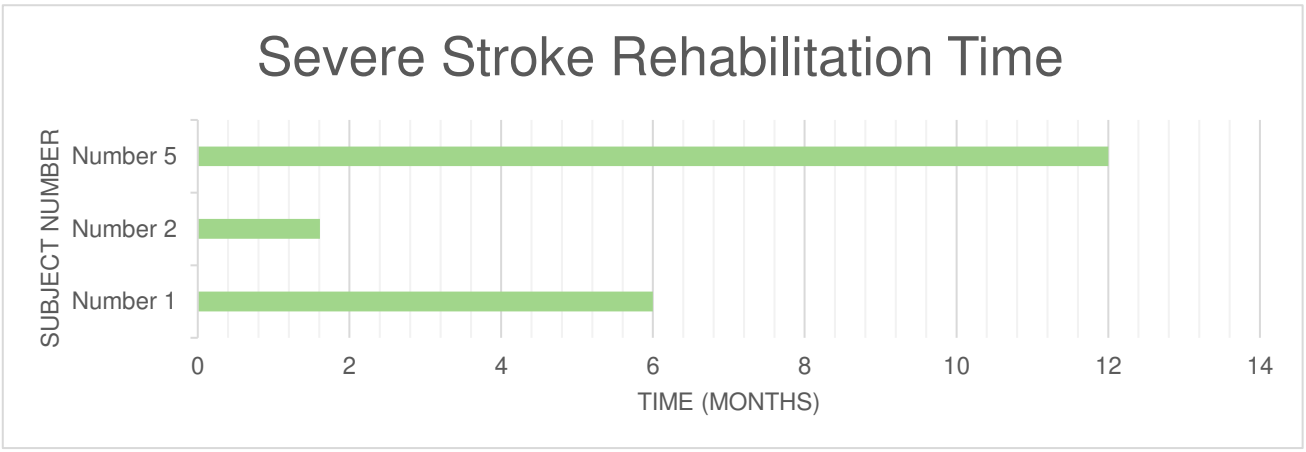
1.1 – Data for Figure 1

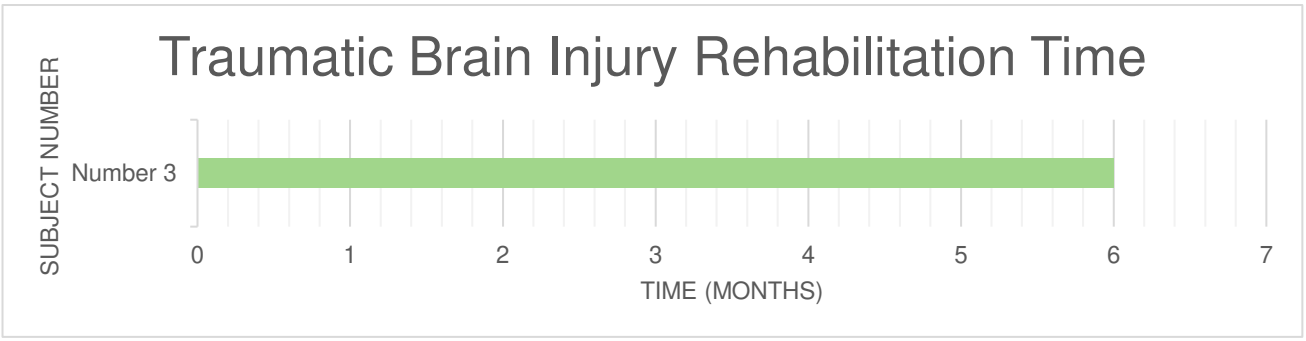
Average Stroke Rehabilitation Time	
Severity	**Average Time (Months)**
Mild-Moderate Stroke	6.58
Severe Stroke	2.87
Traumatic Brain Injury	16

1.2 – Average Data for Figure 1

Mild-Moderate Stroke	
Survey Subject	Rehabilitation Time (Months)
Number 4	0.06
Number 6	1.15
Severe Stroke	
Survey Subject	Rehabilitation Time (Months)
Number 1	6
Number 2	1.61
Number 5	12
Traumatic Brain Injury	
Survey Subject	Rehabilitation Time (Months)
Number 3	6







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2 – Raw Data for Figure 2

Hand Rehabilitation Post-Stroke - Survey Findings				
Survey Subject Number:	Test Subject Email:	Severity	Rehab Session Length (Hours)	Notes:
1	sunflowercircle1@aol.com	Severe	1	
2	rmhesom@gmail.com	Severe	1	
3	annev308@gmail.com	TBI	1 - 2 hr	2hr session time listed as subject 3.1
4	pevans041@gmail.com	Mild-Moderate	20 min	
5	camerondb05@gmail.com	Severe	1	
6	airbornemedic8606@icloud.com	Mild-Moderate	5	
7	edavidlu@gmail.com	Severe	1	

2.1– Data for Figure 2

Average Brain Rehabilitation Session Length	
Severity	**Average Time (Hours)**
Mild-Moderate Stroke	2.7
Severe Stroke	1
Traumatic Brain Injury	1.5

2.2 – Average Data for Figure 2

Mild-Moderate Stroke	
Survey Subject	Rehab Session Length (Hours)
Number 4	0.33
Number 6	5
Severe Stroke	
Survey Subject	Rehab Session Length (Hours)
Number 1	1
Number 2	1
Number 5	1
Traumatic Brain Injury	
Survey Subject	Rehabilitation Time (Months)
Number 3	1
Number 3.1	2