Increased Hand Function Confidence after Ischemic Stroke

Winnie Lai, Haohong Lin, and Himani Patel
Augmenting Human Dexterity – Spring 2021
Term Project Report

Abstract

Ischemic strokes may result in hand paralysis and cause patients to lose confidence in their hand's ability to perform daily activities. We hypothesized that by increasing the strength of an added hand support device, the population's frequency and duration of grasping and confidence would increase. Our preliminary results obtained from an experience-based interview highlighted this lack of confidence and gap in existing devices.

Our concept addresses user needs by making it light-weight and easy to use. The exoskeleton support glove has segmented supports embedded, enhanced fingertip grips, and a LED visual display for grip strength, allowing users to gauge their applied strength.

Three varying exoskeleton materials will be tested to identify which composition can deliver optimal results. The user would grasp three objects when performing specified frequency and duration tests. With the success of this work, ischemic stroke patients will be able to augment both their strength and assurance.

I. Introduction

About 87 percent of 795,000 strokes yearly are ischemic strokes, resulting in paralysis, vision problems, and memory loss. Even after a grueling rehabilitation process, new adjustments to daily living activities have to be made to compensate for skills not fully regained.

One of the most common post-stroke effects include loss of overall body strength and impaired hand functions. While there are existing rehabilitation therapies, there is no guaranteed method for people to completely recover to their former physical state. Patients may lose confidence in their hand's capabilities to perform daily activities, detrimentally decreasing its use and muscle strength over time.

Current devices that exist for increasing hand strength possess some limitations. One example device is a 3-D printed exoskeleton used to augment hand strength. It works well at assisting grasping and pinching force, though gaps remain in comfort and use – specifically the heavy weight of the device. [1] Additionally, it does not focus on users regaining confidence in their hand's ability to securely grasp an object. Therefore, it is important to bridge this gap by developing a device that not only allows post-stroke patients to increase strength but also their trust in their hands' abilities.

A. Background

In the United States, a person suffers from a stroke approximately every 40 seconds [2]; strokes are also a leading cause of long-term disability [3]. They can occur at any age, although they are more common with increasing age. Ischemic stroke is the most common type and occurs when a blood vessel is blocked in the neck or brain. The effects of a stroke depend primarily on the location of the blockage and to what extent the brain tissue is affected. Since one side of the brain controls the opposite side of the body, a stroke affecting the right side can result in neurological complications on the left side of the body including paralysis, vision problems, and memory loss [4].

Rehabilitation is often implemented post-stroke to help patients relearn skills that were suddenly lost as a result of the partial brain damage. With repetitive and customized practice, post-stroke patients are able to regain daily functions; however, rehabilitation also teaches new ways to compensate for any remaining disabilities – for example, learning how to bathe and dress with only one hand [5].

People's quality of life post-stroke is significantly diminished due to added restrictions on their daily activities as a result of their overall physical strength and functions. In fact, over 80 percent of stroke

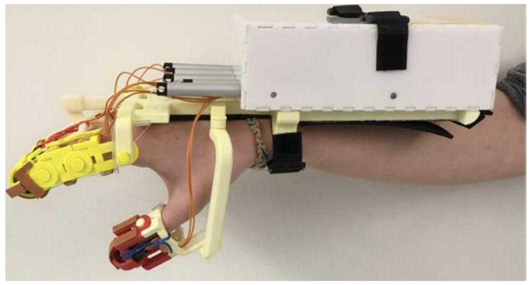

Fig. 1. This figure shows an example 3D printed exoskeleton being tested now as a hand augmentation device. [1]

patients experience problems with hand function due to hemiplegia [6]. This includes side effects such as potential loss of grip and pinch strength, which are both crucial to performing basic daily activities [7]. Specifically with the loss of physical strength and functions post-stroke, these patients require additional support from either other people or devices to perform their regular tasks. There is also a short time constraint of 1 year for recovery of physical functions post-stroke as effects of rehabilitation tend to diminish beyond this period [8].

In addition to all of the aforementioned downfalls of post-stroke life, patients have a difficult time regaining confidence in their previously paralyzed side of their body. Specifically, it becomes difficult to trust their own body's capabilities for daily tasks even after receiving therapy [9].

With the fact that almost a million people in the United States suffer from the weakness of hand strength due to various reasons, novel techniques are applied to build products to augment the human hand strength. One example is a 3-D printed exoskeleton designed for better grasping and pinching [1]. The major structure of the exoskeleton is 3-D printed using durable ABS plastic, which results in a relatively huge saving of the cost compared to using metal materials. This exoskeleton glove is experimentally proven to be effective in augmenting grasping and pinching force while reducing the need of human arm muscle activities. However, this device is very large and heavy and does not address the main concern of regaining trust in the body's ability.

Therefore, a large gap between user needs and existing devices needs to be filled. An ideal device would not only allow post-stroke patients to increase strength but also increase their trust in their hands' abilities to grasp and hold objects. Users seek a device that could be easily integrated into their lives that gives them a quantifiable measure for when they can place their trust in the device. This reliance can slowly translate into confidence in their own hands to ultimately return to their previous daily lifestyle and perform tasks with reassurance.

B. *Overview*

We hypothesize that by increasing the strength of added hand supports, the population's frequency and duration of grasping with the paralyzed hand post-stroke will also increase. This increased frequency and duration is an outcome of the users' confidence level in trusting their hand's ability to perform daily activities, such as holding heavy objects and grasping utensils, for example.

If this hypothesis holds true after testing (Section III-B), it could alter how engineers approach designing strength augmentation devices for ischemic stroke patients by focusing on increased use through user confidence (Section IV). These findings might also hold implications for clinical outcomes of ischemic stroke, specifically hand dexterity strength, grasping abilities, and trust. (Section V).

II. Preliminary Results

Our team conducted an interview over a video conference on Zoom for a duration of 45 minutes. Alongside the interviewee, there was one interviewer, one note taker, and one observer present. The interviewee was an older adult of 85 years who suffered from an ischemic stroke approximately 13 years ago. After taking a long flight from America to India, she went to the emergency room with her first ischemic stroke. After being discharged, she soon returned three days later to the emergency room with another ischemic stroke. This time, the stroke resulted in paralysis of the left side of her body.

The main topics of our interview were categorized into the following: background information, 6 months after stroke, current hand function, daily activities, and current products used. We used the method of contextual inquiry to determine how the interviewee functions in her day-to-day life post-stroke. Through Zoom, we were able to observe her accompanied hand motions when describing tasks she performs daily and some she struggles with. We also observed a demonstration of rehabilitation exercises, for example.

Furthermore, our team embodied the apprentice and expert role, highlighted within contextual inquiry, to ensure the interview revolved around the interviewee, maximized our learning, and strayed from an interrogation or survey format.

Question/Prompt	Customer Statement	Interpreted Need
Current Hand Function	Objects will fall out of my left hand.	The SD should help users hold objects with their left hand.
Likes – Post-stroke Therapy	Most of the exercises were done with my own body.	The SD could be controlled with the user's own body.
Dislikes – Post-stroke Therapy	The therapy took 6 months but I still do not have the same abilities as before.	The SD should be focused on helping users perform daily tasks.
Current Use of Devices	I am just used to living my life without devices.	The SD should be easily integrated into lifestyle.
General adjustments	The hardest task now is using the bathroom.	The SD could have various motions and capabilities.

Fig. 2. This figure highlights the primary user needs determined from interview for our support device (SD).

After conducting the interview, one of our biggest takeaways was that our interviewee did not rely on her left hand, which was previously paralyzed, to perform daily activities. Although she received rehabilitation post-stroke, she expressed that she still did not regain the same functions in her left hand prior to the stroke even after 6 months of therapy. Therefore, this served as one of our primary interpreted needs. We wanted our support device to be focused on increasing confidence in using her previously paralyzed hand and helping her better perform her current daily activities instead.

Furthermore, we learned in more detail about her rehabilitation exercises. Our interviewee informed us that one of the aspects she liked in her previous therapy experience was performing them with her own body. She preferred not to have to figure out how to use a device. Our interviewee also stated that she does not currently use any device in her daily life and is accustomed to this type of device-free lifestyle. Being unfamiliar with the novel technologies, the support device should be easy to use, easily integrated into his or her life, and be able to assist her in performing her daily activities.

With regards to performing daily tasks, our interviewee mentioned she feels a lack of confidence performing daily activities that typically require grasping force – like holding a glass of water. Therefore the interpreted user need was to help increase confidence by augmenting strength.

The most challenging task for the interviewee is using the bathroom. It requires the coordination of many muscle groups and comprehensive hand functions to complete showering, which is hard for people who have experienced some loss of hand functions after ischemic stroke. This pain point requires the support device to be very robust in waterproof and the capability to perform various motion supports.

The primary user needs are highlighted in Figure 2.

These preliminary results support the hypothesis as one of the needs is to provide confidence through augmenting hand strength with our device. We believe that by increasing the strength of added hand supports, users will increase frequency and duration of grasping with their paralyzed hand post-stroke. Through this increased use, the user may feel more comfortable and secure in performing daily tasks with their alternate hand.

III. Methods

A. Device Concept

Our exoskeleton support glove (Figure 3) will help users regain use of the hand that lost function after the ischemic stroke. It incorporates grip capabilities on the fingertips to increase dexterity and ability to grip slippery objects. A layer of sturdy material will be embedded into the glove in segments to allow for easy movement and support for tasks such as lifting objects. With the added support, the user will feel more confident in relying on their hand after rehabilitation; through this increased use, the users are able to augment their muscle strength by increased hand exercise.

There is also a LED display that represents the user's grasping strength. The 5 lights are turned on in proportion to the maximum force, which is detected by the force sensors on the finger tips, applied. For example, 3 of the total 5 LED lights on would represent moderate strength and reassure the user that he or she can be confident in their grip. Also, to prevent very low strength that may result in slip or very high strength that may damage the sensor, the LED will flash all 5 LEDs with a 0.5 second interval to alert the user when these certain forces are applied. The Arduino located underneath the dorsal support will ensure the coding for this task.

This support glove could be worn as the normal gloves, with some adjustment of the size to fit to different types or sizes of fingers, which could be easily integrated to daily activities.

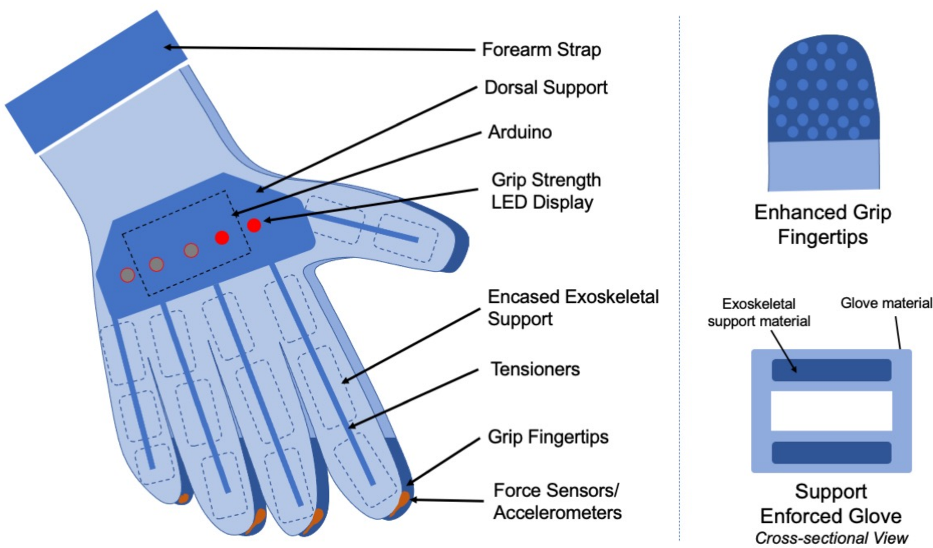

Fig. 3. This figure demonstrates a digital drawing of our ekoskeletal support glove design.

B. Testing

1) Proposed Study: The study is aimed to help post-stroke patients who missed the golden period to fully recover their hand strength and functions to regain confidence via our support glove device. The study would examine our device's ability to help users start using their weakened hand more often again by supplementing them with the additional strength necessary to perform their daily tasks and increase their confidence level.

2) Testing Procedure: The testing procedure is focused on examining the relationship between the strength of hand supports and the frequency and duration of user's grasping motion. To do so, we would first prepare a few different samples of our device with exoskeleton support materials of varying strength. In this study, we would be testing 3 different support materials: steel, aluminum, and titanium. The control sample to compare these samples to would be the user's physical hand without the usage of the device.

The testing procedure for the control and 3 different samples specified above involves the user performing a series of grasping tasks. In this study, we are testing the following 3 specific tasks:

1. Picking up a full cup of water 2. Picking up a pencil 3. Picking up a ball

These tasks are chosen based on objects that we expect most user to commonly encounter in their daily lives. To test the effects of different device on frequency performance for each task, the user would repeat the task as many times as possible in a set time frame. To be specific, we would record how many times the user picks up and puts down an object in 5 minutes for each of the 3 tasks specified above for each of the 4 device testing samples (including the control sample). And to test the effects of different exoskeleton device material on grasping duration, we would have the user hold each object for as long as possible and record the time as reference.

Each of the aforementioned test cases would be repeated 5 times to collect a sufficient sample size for capturing any uncertainties. To ensure that the user's fatigue does not impact the collected result, we would ensure that the user rest for at least 10 minutes in between each test case.

3) Expected Outcomes: All 3 testing samples of the support device (steel, aluminum, titanium) is expected to achieve greater results than the control sample for both the frequency and duration test. Thus, this would prove our hypothesis that the use of our support device in augmenting the user's hand strength can help deliver greater confidence in their hand usage.

Of the 3 different support device samples tested, we expect the titanium sample to have the highest results because its material composition provides a good balance of strength and weight. In other words, a titanium exoskeleton support can result in high tensile strength while still keep the device light weighted. It also has additional qualities of high corrosion and temperature resistance that would allow the user to utilize our device for a greater variety of tasks.

IV. Intellectual Merit

Our device can be of merit to any scientist or engineer in the biomedical engineering field, especially those focusing on hand function recovery devices. Engineers can build upon our device's exoskeleton design and further optimize it to deliver greater strength, structural integrity while still maintaining the user's agility.

Furthermore, users who have experienced ischemic strokes desire a device that helps them regain confidence in using their hands (I-A). This study will help engineers alter their perspective when designing to one that focuses on the feelings behind the user when interacting with a product. If this work is successful, researchers who specify in the field of hand rehabilitation can also take inspiration from our device's design and adapt them for rehabilitation purposes. For example, our device can be modified to include additional strength training mechanisms targeted for different areas of the hand to optimize hand recover of post-stroke patients.

V. Broader Impact

People who have suffered from inconveniences caused by loss of hand strength after ischemic strokes can benefit the most from our design. Our device could help numerous people regain their usage of hand and confidence level – an area that most designs do not highlight. With attributes of easy integration, light-weight, and ease of use, our device has a broader and deeper impact on the recovery of our target group.

Not only does this device help users increase use of their previously paralyzed hand, but it also reshapes their confidence to provide a new perspective when performing daily activities. The broader public has the opportunity to expand upon our idea and incorporate the aspect of increasing user confidence within their own inventions. Hand strength weakness after ischemic stroke should earn broader public care, and our device has the potential to benefit this group of people with low cost and high efficiency.

REFERENCES

[1] E. R. Triolo, M. H. Stella, and B. F. BuSha, “A force augmenting exoskeleton for the human hand designed for pinching and grasping,” in *2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*. IEEE, 2018, pp. 1875–1878.

[2] C. J. Sommer, “Ischemic stroke: experimental models and reality,” *Acta neuropathologica*, vol. 133, no. 2, pp. 245–261, 2017.

[3] S. A. Randolph, “Ischemic stroke,” *Workplace health & safety*, vol. 64, no. 9, pp. 444–444, 2016.

[4] “Stroke.” [Online]. Available: https://www.aans.org/en/Patients/Neurosurgical-Conditions-and-Treatments/Stroke

[5] “Post-stroke rehabilitation fact sheet.” [Online]. Available: https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Fact-Sheets/Post-Stroke-Rehabilitation-Fact-Sheet

[6] C. Yoo and J. Park, “Impact of task-oriented training on hand function and activities of daily living after stroke,” *Journal of physical therapy science*, vol. 27, no. 8, pp. 2529–2531, 2015.

[7] J. H. Bae, S. H. Kang, K. M. Seo, D.-K. Kim, H. I. Shin, and H. E. Shin, “Relationship between grip and pinch strength and activities of daily living in stroke patients,” *Annals of rehabilitation medicine*, vol. 39, no. 5, p. 752, 2015.

[8] L. Dovat, O. Lambercy, R. Gassert, T. Maeder, T. Milner, T. C. Leong, and E. Burdet, “Handcare: A cable-actuated rehabilitation system to train hand function after stroke,” *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 16, no. 6, pp. 582–591, 2008.

[9] S. W. Lee, B. C. Vermillion, and G. S. Heidner, “Restoring proper task mechanics of the hand post-stroke by targeted assistance of hand muscles,” in *2017 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 2017, pp. 1138–1141.

Appendix A
Investigational Device Details

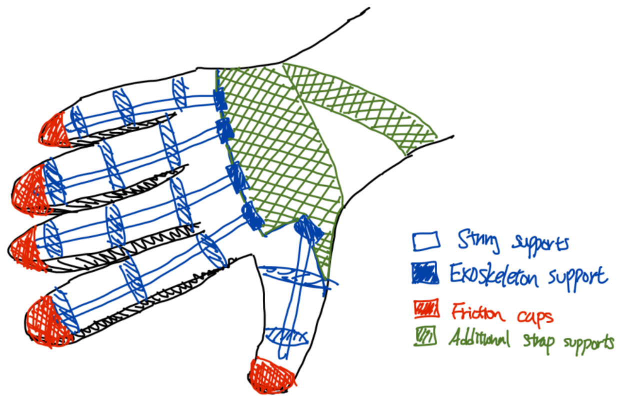

Fig. 4. Initial sketch of design

Fig. 5. Non-functional prototype showing exoskeleton structure (left) and use holding a cup (right)

Our product, represented in the digital drawing in Figure 3, has a very similar appearance compare to the normal gloves. Through the brainstorming (Figure 8) and weighted matrix processes (Figure 9), our team came up with exoskeleton device and finger grip idea as our most valued concept. Therefore, we decided to combine those two ideas so that our device is composed of both enhanced grip fingertips on the outer surface of glove and the exoskeleton structure within the glove.

The main structure of the glove is composed of two layers of normal glove's material, with the exoskeleton device embedded in between the two layers, and an Arduino board with five LED on the back of hand. This is to make sure that the device could have a similar appearance to a normal glove. From the cross-section view on the right bottom side (Figure 3), you could see that the exoskeleton device is wrapped by glove materials to allow for comfort to the user of soft material in contact with the skin while feeling the support of the exoskeleton structure. Another aspect of this design is that the glove material could protect the user from potential damage from exoskeleton structure in scenario that the structure is broken because our interviewee is not familiar with exoskeleton device. There are more design details like forearm strap, which is used to prevent the glove from falling off the user, and the dorsal support, which strengthens the exoskeleton structure. The fingertips of our device is composed of two parts. One is encased exoskeleton support, which is used to fit each dactylus of finger. Another is tensioners that lay across all the encased exoskeletal support to hold the structure.

Another design feature is the enhanced grip fingertips for increasing friction when grasping a slippery object. This could largely enhance the confidence of use of hand when they approach curved objects with less friction on the surface, like a glass of water, for example.

Furthermore, the LED display quantifies the user's grasping strength in a visual manner. The 5 lights are turned on in proportion to the maximum force, which is detected by the force sensors on the finger tips, applied. Also, to prevent very low strength that may result in slip or very high strength that may damage the sensor, the LED will flash all 5 LEDs with a 0.5 second interval to alert the user when these certain forces are applied. This would be accomplished through the accelerometers embedded in the fingertips that would indicate when an object is intended to be lifted or moved. If not enough grip is applied, then the alert would inform the user. The Arduino for these tasks is located underneath the dorsal support.

The inspiration of the design came from our background research and interviewee, as she was afraid to use her paralyzed left hand even after rehabilitation training. The overall weakness of hand causes issues including dropping of cups and other activities of grasping. Our design could increase the use of the weak hand after ischemic stroke by allowing our interviewee, or other users in similar condition, to feel like they have a stronger hand to perform daily tasks when wearing our glove. The enhanced grip fingertips also make sure the user could grasp things even with less strength, which could improve their confidence to use their hand more frequently in daily life. The light weight design is also extremely suitable for people who have overall weakness of the whole arm other than just the hand.

APPENDIX B
COLLECTING AND ANALYZING INTERVIEW DATA

A. *Question Preparation for Interview*

1) *Beginning Elements:*

- Thank participant for agreeing
- Remind that they can stop anytime and do not need to share anything they do not want to
- Can we get permission to record the audio or video
- Remind that data will remain confidential
- Introduce our team, team members and our course project
- Gives a rough agenda about today's interview and what to expect to answer
- Any questions before beginning

2) *List of Topics and Questions:*

1) Tell us about yourself.
    - Age
    - Location
    - Hobbies
2) Tell us about the stroke you had.
    - When did it happen?
    - Were you taken to the emergency room? How long did you remain in the hospital?
    - What was the diagnosis by the medical professional?
3) How was your body affected in the week after the stroke?
    - Did those symptoms disappear?
    - How long did that take? Which ones remained?

- What did you find easy and difficult to do?

4) What is your current state of hand function?
   - Have you recovered from the stroke?
   - Do you find anything different with your hand function between now and before the stroke?
   - Is there a difference in your pinch or grip function after the stroke?
5) Did you take any therapy or treatment afterwards?
   - Tell us more about this therapy.
   - What devices they did use to help you? (Follow up on the product details)
   - What did you like/dislike about the therapy?
6) Do you use any products to assist you during recovery?
   - Are you aware of any products that can help you with this?
   - When and why do you use this type of product?
   - What has prevented you from using those types of products?
7) Do you use any products to assist in daily life right now?
   - What is product and its purpose?
   - If unaware, what contributes to lack of knowledge.
   - Do you face any difficulties? Looking for any improvements?
8) Tell us about your daily activities.
   - Do you receive assistance for any of them?
9) What did you do today when..? (Ex: eating lunch, getting ready in the morning)
   - Rank how difficult these examples have become post stroke compared to before (1-5)
10) Do you know anyone who also had a stroke but facing different difficulties than you?
    - Information about the person?

3) Concluding Elements:

- Thank participant for their time
- Remind them that data will be kept confidential
- Explain next steps
- Any follow up questions

4) Roles: Interviewer: Himani Patel

- ask questions
- communicate with need knower

Note Taker: Haohong Lin

- write down exacts words
- document interesting quotes and facts

Observer: Winnie Lai

- view nonverbal cues
- make sure nothing important is missed during interview

B. Interview Analysis

Our team analyzed the key takeaways from the interview and developed a user needs chart (Figure 6) and hierarchical needs summary (Figure 7).

Question/Prompt	Customer Statement	Interpreted Need
Current Hand Function	From my wrist up, I do not use my left hand as often.	The SD could allow the user to use left hand more.
	I can't really hold anything heavy with my left hand.	The SD should help user hold heavier objects.
	I had to make adjustments to my dressing style and daily activities after the stroke.	The SD could help the user perform daily activities in a manner similar to before.
	Objects will fall out of my left hand.	The SD should help user hold objects with left hand.
Likes – Post-stroke Therapy	I like the hand recovery exercise such as squeezing exercise	The SD could be attractive and interesting to them.
	Most of the exercises were done with my own body.	The SD could be controlled with own body.
	I liked the heat pad on my shoulder.	The SD could implement heating device to alleviate muscle pain.
Dislikes – Post-stroke Therapy	I was nervous to rely on the left side of my body.	The SD should be reliable and arose user's confidence.
	I stopped cooking and had a hard time holding a glass of water or buttoning my shirt.	The SD could focus on augmentation strength recovery.
	The therapy took 6 months but I still do not have the same abilities as before.	The SD should be focused on helping user perform daily tasks.
Current Use of Devices	I am just used to living my life without devices.	The SD should be easily integrated into lifestyle.
	I use a cane with my right hand only.	The SD should allow for motion with both hands.
	I do not like using my hearing aid either because it is annoying.	The SD allows the user to engage easily and has a desire to be used due to its benefits.
General adjustments	Due to COVID, I am performing less activities to engage my hands compared to what I would in my adult daycare center.	The SD could allow user to engage in more a daily activity with increased hand use.
	I have grown accustomed to my lifestyle.	The SD should be not disturb user's daily routine/habits.
	The hardest task now is using the bathroom.	The SD could have various motions and capabilities.

User-need chart. This table presents the customer statements from the interview and the respective interpreted needs for an ideal support device (SD).

Fig. 6. This table highlights the user needs chart from customer statements

(1) The SD is effective
** The SD is training the user in a professional manner

(2) The SD is reliable/durable
* The SD lasts a long time
The SD is made of sturdy materials
* The SD does not break easily/can be fixed quickly if it does

(3) The SD is easily integrated into the user's life
*** The SD is easy to use
* The SD is not large and bulky
** The SD does not significantly hinder daily activity

(4) The SD is easy to control
** The SD is easy to stop or start even in some strength training process
The instructions for the SD are clear

(5) The SD can provide training for different scenario
*** The SD can help recover different hand function
* The SD has different function to train different part of muscles

(6) The SD is adjustable for different users
* The SD can be customized for different hand sizes
*** The SD can be used on the left or right hand
* The SD has a relatively large range of training load

(7) The SD helps the user regain confidence
** The SD helps recovery of hand function
The SD ensures user of their hand capabilities over time

(8) The SD can help regain most function
The SD helps user perform daily activities prior to stroke

(9) The SD feels good in the user's hand
* The SD is comfortable on the hand
The SD is balanced on the hand
*** The SD does not fall of the hand
** The SD is not too heavy
The SD can be used in varying climates

(10) The SD is safe
** The SD does not add unnecessary pressure to user
** The SD does not pinch the skin
* The SD is not heavy
** The SD has no sharp edges
*** The SD has emergency stop function

(11) The SD is easy to store
* The SD does not take up too much space
** The SD can be stored at room temperature
* The SD can resist water damage

Hierarchical list of primary and secondary needs for the recovery device. Number of *'s indicates importance, with more representing more important needs.

Fig. 7. This figure showcases the hierarchical needs developed from the interview

C. Brainstorming Divergence

The following process was used to brainstorm ideas:

1) First, each member individually developed 5 ideas for hand recovery device (RD).
2) Then, we each voted on the others' members ideas to select which specific ideas to expand further on
3) Next, we utilized the 3-2-20 brain-writing technique in which each member expanded on one idea for 2 minutes then rotate to a different idea.
4) After the above brainstorming sessions, we've generated a total of 20 ideas for the RD.

Fig. 8. This figure showcases the brainstorming of ideas.(red=support, green=strength - squeeze, blue=strength - lift, purple=grip)

D. Idea Convergence

To evaluate our ideas, we categorized them into 7 groups (Figure 8), based on redundancy and overlap, and ranked them on a scale of 1-5 for the following criteria: ease-of-use, safety, effectiveness, cost-effective, reliability, customization, integration, and novelty.

Metric	Weight (1 - 5)	Exoskeleton Support Glove	Finger Grip Glove	Forearm Strength Builder	Squeeze Exercise Glove	Fingertip Attachment Prosthetic
Ease of Use	5	3.67	4.67	3.33	4.33	3.67
Safety	3	4.33	5	3.33	4.33	3.67
Effectiveness	5	5	3.67	4	3.67	4
Cost-Effective	2	3	4	2.33	4.33	3.33
Reliability	2	4	3.67	3.67	3.67	3.67
Customization	3	3.67	2.33	3	3	3.33
Integration	4	3.33	4.33	2.67	3.67	4
Novelty	3	4	3.67	4.33	3.67	3.67
TOTAL		**107**	**107**	**91**	**104**	**100**

Fig. 9. This figure shows the final results of our weighted matrix after our idea convergence

After group discussion, we decided to have our final idea be an exoskeleton support glove, with added finger grip capabilities, to help our customer regain use of the hand that lost function after the ischemic stroke. The glove will have a layer of sturdy material embedded into the glove material to increase strength and support for tasks such as lifting objects. Additionally, they will be segmented into sections representative of finger segments to allow for easy motion. The fingertips will have an external material that allows for increased grip function. III-A