DexPlay: Dampening Wrist Vibrations to Empower Musicians with Essential Tremors

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Abstract

Essential tremors involve involuntary movement of the hands. While there is no permanent solution, assistive technology offers a viable treatment when medication or surgical procedures are not ideal. The use of wrist weights are common solutions, but can be bulky and attention-drawing. Moreover, while these devices may be effective for mitigating tremors during routine activities, there is an opportunity to mediate tremors for niche tasks. From a case study with an interviewee, guitar playing was identified as an activity that was given up due to ergonomic challenges introduced by tremors. To address this, the team introduces DexPlay, a passive device for guitar players that aims to dampen vibrations from the left wrist. The design utilizes an angled beam and a custom spring board that is sensitive enough to compress with minor wrist movements, limiting the amount of shaking while allowing the user to reach across the neck of the guitar. A series of tests are proposed to assess the prototype and gather efficacy and usability data. The result is a customizable product that encourages musicians with essential tremors to pick up the guitar once again.

I. Introduction

Essential tremors (ET) are a neurological disorder that involves involuntary movement of the body, typically involving the hands. Approximately five percent of the worldwide population experience this condition, and nearly fifty percent of the cases are due to genetic inheritance [1]. Unlike Parkinson's disease where the limb shakes when the individual is at rest, ET often occur when the individual is performing an action [2]. This consequently makes it difficult for those with ET to complete tasks that require precise movement and positioning of the fingers. In particular, the team is interested in addressing the challenges posed by playing the acoustic guitar. Due to the strings' thin size and close placement to each other, pressing down on the correct location can be difficult especially when the hand is shaking [3]. Moreover, while it is possible to mitigate the effects of ET by having a firmer grasp of the guitar's neck, this adds a significant amount of stress in the hand and shortens how long the instrument can be played in one sitting. By limiting the shaking motion of the hand with DexPlay, the team hopes to help individuals with ET reclaim their hobby and passion.

A. Background

Although there currently is no permanent solution for ET, treatments can mediate their effects. These solutions are divided into three categories: medication, procedures, and assistive technology.

The FDA has approved propranolol (beta blockers) for ET, but other medications including benzodiazepines (anxiety and muscle spasm sedative) and anticonvulsants (seizure medication) have been proven useful [4]. Major drawbacks include cognitive side effects like slower response times.

In the case of medication-refractory tremors, surgical procedures like deep brain stimulation (DBS) can be explored. DBS is implemented through an implanted electrode that stimulates the brain [5]. Regions like the thalamus that govern movement are targeted with electrical pulses, thus improving motor symptoms [6]. Although this is the most effective treatment, it requires a detailed operational procedure. Another recently developed surgical method is MRI-focused ultrasound platforms, which received FDA approval

in 2016. This non-invasive procedure passes ultrasound waves through the skull to destroy brain tissue responsible for ET [7].

A more accessible option for individuals with ET is assistive technology. The most common form is wrist weights, and many devices utilize a similar approach to slow trembling movements. For instance, Readi Steadi is a customizable glove that can add multiple low-profile weights depending on the user's need [8]. Similarly, Tremelo is a wrist brace with a purely mechanical tuned mass damper to counteract tremors [9], while the Steadi-Two glove uses a magnet-based vibration absorber [10]. Although all three of these devices have proven efficacy, they are often bulky and unattractive, making them less appealing. More sophisticated versions have been proposed, including Cala Trio, a wearable neurostimulation device available by prescription, as seen in Figure 1. This device can be worn on the wrist and targets the medial and radial nerves, communicating with the sensorimotor cortex of the brain to provide temporary relief after a 40-minute treatment [11].

((a)) Steadi-Two

((b)) Cala Trio

Fig. 1: Existing assistive technology for ET include vibration absorber gloves like Steadi-Two [10] and neuromodulation devices like Cala Trio [11].

While the majority of ET treatments aim to mitigate the general effects of the condition, they are not designed to improve performance with a specific activity. Consequently, the team wishes to distinguish itself from competing products by targeting ET in musicians. Further narrowing down the problem, the team hypothesizes that by dampening the flexion/extension motion of the left wrist holding the guitar neck, the shaking motion caused by ET will be reduced and the user will be able to press and hold individual strings with more ease.

B. Overview

The team interviewed an individual with ET to determine their interpreted needs, and the results are discussed in *section II*. In *section III*, the team proposes a device with the potential to dampen the shaking motion in an individual's wrist using springs and the coupling of moments. The prototype's main mechanism, in addition to the thought process behind it, is also explained in this section, with references

to supplemental material in appendix A and B. Furthermore, *section III* contains various testing methods to verify the efficacy of the device, such as asking potential users to hold a guitar with and without DexPlay or using an accelerometer attached to the device to measure vibration frequencies. Finally, the impact of future research on assistive devices for ET and how it will affect those with the condition are discussed in *sections IV* and *V* respectively.

II. Interview Case Study

The team interviewed a middle-aged individual with essential tremors to gain a better understanding of their experiences. They shared some of their personal values, beliefs, and motivations, including how they have been treated by society because of their condition. Additionally, the interviewee gave the team feedback on existing products they have tried and opened up on what daily life is like with ET. Of the various details shared, the team was specifically drawn to the interviewee's interest in playing music. As a musician, they are able to play the trumpet, bass guitar, and drums despite the effects of their condition. Nevertheless, they explicitly mentioned having to give up learning acoustic guitar because of tremors, and the team identified this as a niche task to address for the project scope.

Following the completion of the interview, the team created a list of interpreted needs based on the interviewee's answers. These were then organized by the category of the prompts and prioritized based on interviewee and team preferences. Once this was done, each team member placed a dot on their top five choices to identify the primary needs to pursue as a team. The results and their corresponding interview statement are shown in table I. The full hierarchical list of needs and the dot method used can be found in Appendix A.

Prompt	**Interview Statement**	**Interpreted Need**
How They are Treated by Other People	"[Essential tremors] make you look unconfident... I think it has affected me in the past. Just the way you're seen."	Feeling confident in themselves when around others and not be seen as someone with a disability
Tasks that They Struggle With	"I only went so far with acoustic [guitar] because it's really hard. The strings are very close together and thin..."	Feeling empowered by their ability to regain a part of their life that they had to give up due to their condition
Thoughts on Using Assistive Devices	"If it really helped enough to make it worth it, I would do it... It would be dependent on how effective it would be for the smaller tasks."	A device that makes a noticeable and meaningful difference when using it to accomplish tasks with smaller objects
Thoughts on Using Assistive Devices	"Nobody wants to have a sign. You know, on their arm that says, 'Look at me.'"	A discreet device that can help mitigate embarrassing situations and unwanted attention

TABLE I: Key needs identified from the interviewee's responses.

The first need identified by the team was the interviewee's desire to feel confident. They shared their dislike for being seen as someone with a disability and wants to avoid attention drawn to their tremors. The second need was the feeling of empowerment. Having given up the acoustic guitar due to the effects of ET, the interviewee expressed interest in learning the instrument to prove that tremors did not define who they were. The third need was for a device that actually helped mitigate their condition. The interviewee has tried other products but does not use any of them regularly due to their inability to make a significant difference. The final need was for a device that is useful while being discreet. The interviewee wants to avoid being the center of attention, especially if they are wearing something that warrants that behavior.

III. Proposed Device & Test Methods

A. Proposed Device

Following the concept generation process in Appendix A, the team analyzed the grip required to hold the guitar neck. After several iterations, as seen in Appendix B's prototypes, the team created DexPlay, a passive device that utilizes springs to absorb wrist vibration in flexion and extension directions. Figure 2 shows the device in its straight and bent states, as well as a brief functionality description.

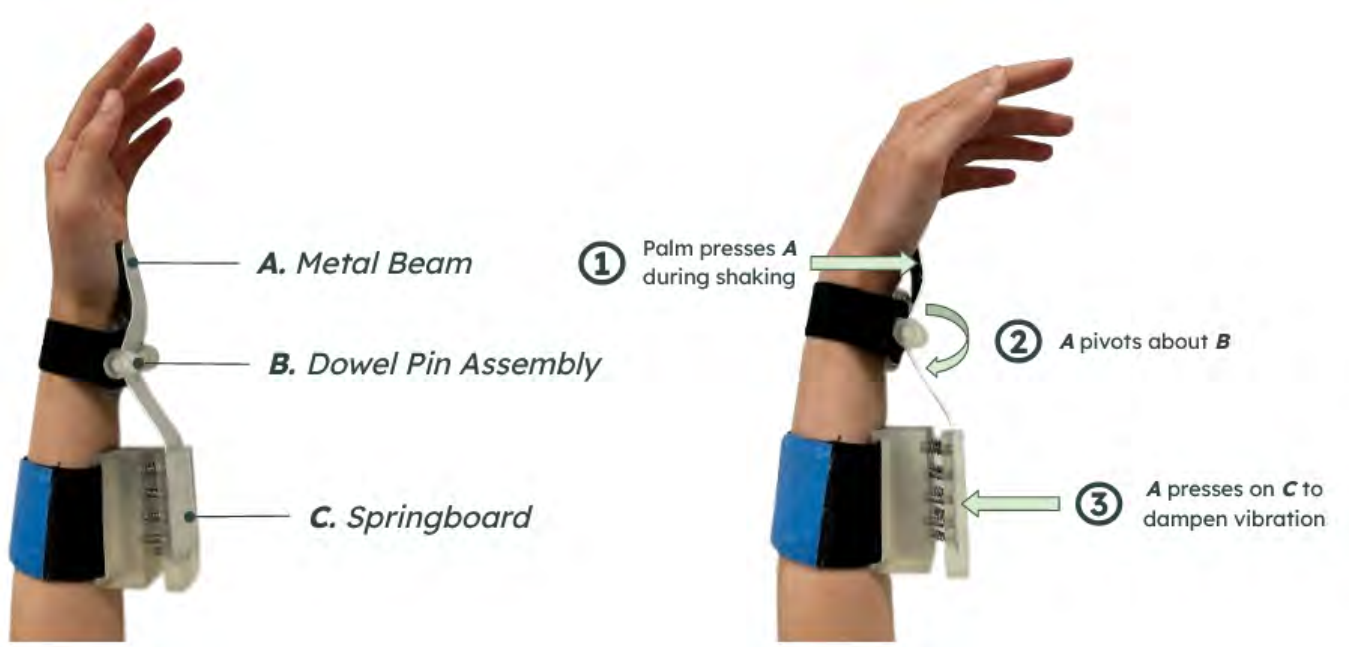

Fig. 2: The proposed devices features a spring board connected to an angled metal bar, creating a seesaw mechanism that absorbs vibrations in the flexion/extension direction of the wrist.

At the top of the device is a metal beam bent to a "V" shape with horizontal extensions on each end. It has a circular indent at the palm and is attached to a thin foam pad to comfortably cup in the hand. Moving down the device, there is a dowel pin assembly that is attached to an elastic band and is secured onto the wrist. It holds down the metal beam and creates a pin joint, allowing the beam to seesaw: as the user's wrist flexion presses down on the upper part of the beam, it rotates clockwise and pushes the lower end onto the spring board. Because this spring board is attached to another elastic band secured onto the forearm, any force exerted by the metal beam is absorbed by the spring's compression. This action is sensitive to small movements due to the springs' low stiffness, limiting the shaking experienced by the user.

The spring board's configuration can be seen in Figure 3. Because motion of the beam is rotational rather than vertical, there is a horizontal component to the force that causes shear as seen in Figure 23 in Appendix B. To address this, the four larger springs spread across the top edge are slightly stiffer than the smaller springs on the sides to allow a slanted press of the metal beam. This reduces the pressure by better distributing the force rather than having the entire load on the bottom edge of the beam, as seen in Figure 25 in Appendix B. The lone spring prevents the spring board from bottoming out.

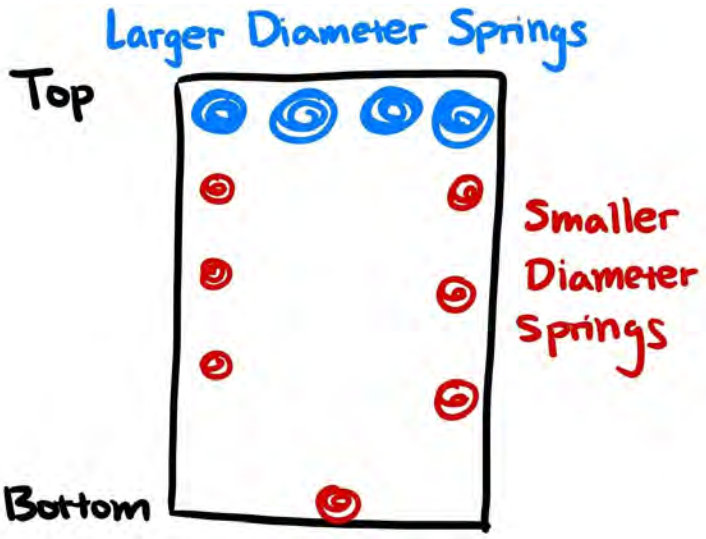

Fig. 3: There are no springs in the middle of the board for less overall stiffness and more compression.

DexPlay is designed to fit on the user's forearm so that the audience can only see the two elastic bands securing the device. This offers the advantage of discretion while providing the benefits of an assistive device, allowing the user to play the guitar confidently.

B. Test Methods

When testing DexPlay, the team aims to address whether it effectively minimizes tremors during guitar playing and whether the design is a reasonable solution for the user.

First, damping efficacy data should be collected by measuring vibrations exclusively at the wrist. This test will focus on wrist movements and will not address whether other limbs such as the forearm or fingers should be addressed. A tremor-simulation glove [12] worn by a team member will be acceptable for initial testing; if the device is proven effective, a follow-up study could be conducted with individuals with ET. The user will be asked to press simple chords on a guitar with and without DexPlay. A piezoelectric sensor or an accelerometer attached to the wrist pin joint will be used to measure vibrations during these two tests, and the reduction in values can be quantified by comparing signal magnitude and frequency. Additionally, because the interviewee expressed gripping harder as a habitual method of minimizing tremors, a separate study should focus on evaluating whether the device is effective at reducing the user's grasp force on the guitar neck. This can be measured with force-sensing resistors (FSR) attached along the MCP joints of the hand. Human subjects with ET are ideal for this test due to their gripping habits, allowing DexPlay's effectiveness to be compared as a stand-alone device.

Second, usability data should be collected by requesting individuals with ET to play guitar while wearing DexPlay. Individuals selected for this study should have varying levels of guitar experience to provide a wider range of feedback. For instance, a participant with zero experience may provide unexpected information on how someone with ET learns new fine-motor tasks. A participant with experience playing guitar, conversely, would provide situational insights and interact with the instrument on a more advanced level. The team would request that the participant play barre chords (index finger presses multiple strings at once) or other challenging chords to test whether dampening vibrations at the wrist is enough to reduce the effects of tremors in the fingers. From usability testing, the team would gather direct feedback from need-knowers by observing their reactions with the product and noting any concerns. In order to conduct this research with human subjects, the team would submit a protocol for review through the Internal

Review Board for the Protection of Human Subjects. All team members have completed CITI Training Group 1 for Biomedical Research Investigators as of April 17, 2023.

IV. Intellectual Merit

In *Section I-A*, the team hypothesized that the wrist motion in the flexion/extension direction was the primary issue. Although existing products provide general solutions, the team proposed a novel damping system that addresses the niche task of accurately pressing guitar strings. The team identified the critical direction of the shaking motion at the wrist through rapid prototyping and observation, as seen in Figures 19 and 15 in Appendix B. Moreover, the team tested various damping materials, seen in Figures 18, 21, and 23, which revealed springs to be most useful. While the spring board was designed using the resources available, a higher-fidelity product would reduce shear stress and optimize compression. The springs would also bend straight down, allowing proper force measurements.

Although there is noticeable resistance experienced by team members when using the device, they acknowledge that DexPlay is localized to the wrist and does not address shaking at the fingers. Further research needs to be conducted to determine if DexPlay should extend to individual fingers. Additionally, the method proposed by this paper only addresses motion in the flexion/extension direction. The effects of wrist abduction/adduction have to be investigated to prove the device's efficacy.

V. Broader Impact

While weighted wrist braces are the most common product for people with ET, the team's interview revealed that they are viewed as bulky and inconvenient. Consequently, the team proposed an alternative that replaces the weights with a damping system on the inner forearm. The device is lightweight and discreet, avoiding the appearance of an assistive device and making it attractive to those that do not want to stand out. To improve comfort, the team plans to make the design open source so that users can adjust the size of the parts; for instance, the metal beam could be modified and 3D printed to accommodate hands of all sizes and shapes. Moreover, the team hopes that this design will inspire new devices that address other niche tasks with varying neutral positions of the hand, allowing those with ET to regain a part of their lives.

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APPENDIX A
DESIGN PROCESS

Question/Prompt	Customer Statement	Interpreted Need
Behaviors that trigger tremors more than usual	"Like right now I'm not feeling that great, and that's why I just actually noticed it, because I was wondering why my hands were so bad… things like sickness… even stress or nerves, that can definitely affect it in certain ways."	Ways to deal with stress or nerves
	"You know there's different elements, even the way you eat. Like I've tried, you know, going completely off sugar and all of those kinds of things which does help. But I'm not that strong. …So I've tried that stuff, and it does help to an extent."	A lifestyle change that mediates effects of tremors to an extent and be worth the sacrifices/risks
	"Anytime I have to hold something like this is really big, you know, like a big water bottle, so it's not really. I can kind of hold something like this. But if it's really small, you know, like this, you can kind of see it, because I'm really grasping more."	Ways to stabilize smaller object when he's holding them
	"Usually I'm able to kind of grip hard enough around the back side of a bass to be able to kind of control it a little… But I don't think it's good long term."	Ways to stabilize the bass in a longer period of time when he's playing
Things/times he's had to give up something or move on from due to tremors	"I only went so far with acoustic [guitar] because it's really hard. The strings are very close together and thin, so it's really hard with tremors to really get very good at it… If you're on stage and all of a sudden your hands are just [bad], there's not a lot of control. It's just gonna sound bad, whereas bass you can probably fake it a little better because the strings are so far apart and a lot thicker. There's more to grasp."	A way to grasp and have control over small, close-together objects
	"Even Sunday I had to pass up something that I just thought I wouldn't be able to do because of the way my tremors were that day. So just depending on what I'd go to do, there are certain things."	A way to control the symptoms when he's interacting with people when working in the church

	"I did a wedding… and I had to tell the couple that I had to have a stand. I wouldn't be able to hold, you know, a Bible or any of those things, my notes… like I would have to have a stand which you don't normally see at a wedding… which is kind of an awkward thing… You're probably not going to be the first choice for weddings if you have tremors, it just doesn't put a lot of confidence. Not necessarily in my ability to do it, but that it would be a distraction, or 'Well, now, we gotta have a stand here.' Or if I go to do a funeral or any of those things."	A less awkward way to receive accommodations for his tremors during public speaking
	"If I'm doing something with public speaking or whatever it is, and it's at a new place... I always have to think about that like okay, what am I gonna need? Do I need to bring a stand? Is it going to be a handheld mic? For some that wouldn't even matter, like they wouldn't even have to think about that because that's not going to affect them one way or the other. So I'd say it's just different… Now it's just more like something I always have to have in the back of my mind so I'm prepared."	A way to control the symptoms despite the environment he is in
Ways to suppress effects of tremors	"The way my hands are [during typing], you know the way you position them, and all depending on how I'm doing it, it's gonna be more noticeable. I kind of rest my arms and my hands [with a standing desk]... You can stand with it, or you can, you know, bring it all the way down, so that I'm able to kind of rest my arms and my wrist there to where it's really not as noticeable… The only times I can remember where I really struggled with that is when there's more pressure. you know, maybe anxiety."	Places to rest his hands and arms and a way to deal with pressure and anxiety
Thoughts on using products or medication	"I've seen things like…some kind of weight you put on your hand, or something like that. I've seen things like that. I've never done it."	The opportunity to explore different solutions
	"I've tried medicine for it. But it…slows your brain. I don't know how to put it… where you're, you're a lot slower. So it	A way to mediate effects of tremors that has more benefits than side effects

	affects me. Like the medicine that is supposed to slow down your tremors, it slowed down so it's down thought process processes, and all of that makes you forget. So I'm trying to stay away from the medicine for that reason."	
	"But I have heard of like things… It kind of weighs down a hand, and that can kind of help, but it also, you know it's pretty obvious you're wearing it. But if something like that would would help, you know I would try it."	A more discreet and visually appealing way to minimize tremors
	" But it's also… I think [the person he knows that wears an assistive device for tremors] … she had to drive… you know she had to go out of town to get it… So I've just never been that motivated to do it…But that definitely is, you know, because really, if I'm thinking about it, I would have to."	Readily available help and more accessible solutions
	"And it didn't really fully resolve it for her, but her tremors may be much worse than mine though where it's… at least she has some form of control. Whereas mine is kind of up and down, and I've kind of grown to be able to hide it as best as I can, and still do some… most of the things. Even if not to the level I would like to. I'm still able to do most of those things."	Significant enough improvements/efficacy that are worth the costs/risks
	"It's not like a… design, you know. It's not a fashion item. It's almost like when you see the wrist things on people's arms. Or like they broke their arm, or something like it's right across like their hand."	Draw minimal attention and not resemble a cast for someone with an injury
	"So for me it was almost like… Well, I'd probably have to have 2, which, if it really worked, then I don't think I really care because… if it helped enough to make it worth it, I would do it, but I think the accessibility of it. It's kind of pushed me away from even checking it out as well. Because it's not something readily available and maybe it hasn't gotten bad enough to where it's just completely debilitating, and I can't function without it."	Suppress the symptoms in an accessible way and shows him that there are clear differences before and after

	"If I was going down that route [of playing acoustic guitar] and really wanting to get better at that, then I think I would [try an assistive device], because it would. You know it would enable me to do that like if there were things that were really like the stuff that I'm doing regularly that are really difficult."	Minimize tremors during specific niche tasks, particularly ones he has had to give up
	"You know that I have to turn down things just because of the tremors, I definitely think, especially those occasions I would."	Be able to do things that he normally couldn't do because of tremors
	"People have the apple watches, and they have the android watches and all of those things, so I don't… care too much… whether I'd have to keep taking it off or…putting it on. But yeah, if it was beneficial and available."	Has a clear benefit and is readily available, doesn't care about having to interact with something constantly
	"I guess, dependent on how effective it would be for the smaller tasks… I think I would. Especially if it… if it worked, you know, if it actually worked."	Be able to do specific tasks for a short duration without much issue
	"Nobody wants to have like a sign. You know, on their arm that says, 'Look at me', you know, like that that wrist thing I think, for I've only ever seen older [people]… were really wearing it.	Discretion but not at the cost of efficacy
	"And I would probably be more apt to try something technology because I work in technology."	Wants something involving technology
How other people treat him	"It makes you look unconfident…I think it definitely has taken some confidence from me because when you deal with that you get so many comments and you get the jokes."	Be more confident about addressing his condition with others
	"When you're typing or something when you're at work…and other people are seeing it, you know they're not going be like man what's wrong with you, but you know it definitely affects [your confidence]."	Be more discreet about the effects of tremors when with his coworkers
	"With public speaking, I kinda use it as almost a motivation thing. I'm still doing it, and that was something I wouldn't do	Reclaim his condition as something that motivates him to do things

	because I didn't want it to be a distraction and all people would be worried about is my hands."	
	"If you want to move up into a position, even in an organization, I think it has affected me in the past. Just the way you're seen."	Does not want tremors to be something that holds him back in a professional setting
	"Maybe some of that stems from a loss of confidence when I was younger because of this, because obviously it's not a fun thing to have in high school. You're picking up the tray and you're trying not to just spill that or whatever for lunch."	To not be embarrassed in front of others, particularly among peers
	"It's not like someone has verbally said, you know we're not gonna give you this particular opportunity or you can't do this because of that, but it's been kind of like, you know, I'll probably pick this person first."	Be treated equally and not be seen as someone with a disability
	"It doesn't necessarily mean they're nervous because they have tremors. But I understand why someone would think that, because if they're seeing someone, especially someone on a stage."	Convey to others that he is not nervous in public settings

Fig. 4: Full list of needs gathered from the interview. The team members asked questions in a certain category and wrote down direct quotes from the interviewee. These were then translated into an interpreted need determined by the team.

***Product can help him grasp onto things**
**Product can help stabilize his hands when holding smaller items
Product can stabilize the bass for long periods of time when he's playing
***Product has a clear benefit when using it versus not using it
Product can help him do things that he had to give up because of tremors
*Product is easy and intuitive to use

****Product is discrete**
**Product draws minimal attention
Product does not resemble a cast for someone with an injury
**Product is not unnecessarily heavy

****Product helps him avoid awkward situations with others**
Products that are aesthetically pleasing
Products that will not be easily recognized as assistive devices
*Product is well-suited for public speaking environments
Products that are not reminiscent of braces for older adults or people with injuries (i.e. cast)
**Product makes him feel confident

***Product is beneficial in multiple environments**
*Product can be used with more than one task
*Product can withstand extreme weather conditions

****Product does not have dramatic side effects**
Products does not affect his thought process
***Product will not be detrimental to his body in the long term

***Product involves advanced technology**
Product has an interesting, innovative concept
Product is high(er)-tech

Fig. 5: Needs were grouped into related categories and rated hierarchically by what the team deemed important. Three stars next to the need was something that the team wanted to prioritize achieving, while no stars was a need that could be addressed later on.

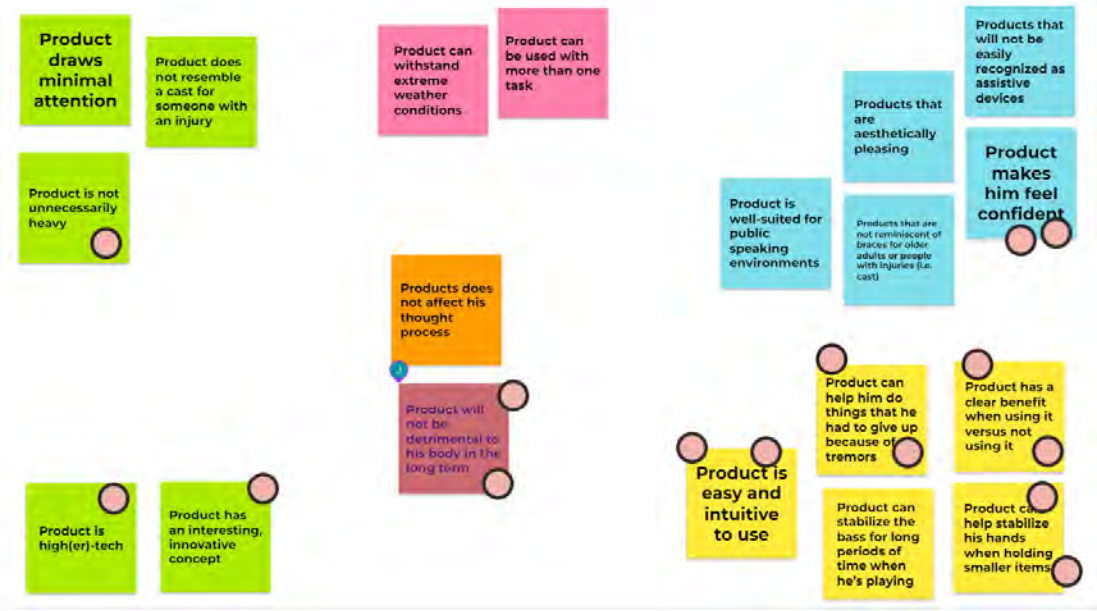


Fig. 6: Dot voting method used by the team to select the top needs to pursue within the project scope. Primary needs of the interviewee included the product making them feel confident, as well as having a device with clear benefits when in use.

Fig. 7: Brainstorming sticky note sketches that are clustered by categories, such as devices revolving around springs or the use of a pulley system.

Requirements	Weight	Spring Glove	Gyroscope Belt	Electrode Patches	Latched Glove	Electromagnet	Buttonpad Guitar	Magnetic Guitar Slider	Arm Beams
Makes him feel confident	1	1	5	4	1	3	4	4	1
Easy and intuitive to use	1	5	3	3	4	3	4	4	3
Helps do things that had to be given up	3	9	9	9	9	12	6	6	9
Stabilizes hands when holding small items	2	6	4	4	8	8	2	2	6
Clearly beneficial when using versus not using	1	2	2	2	3	4	4	4	3
Feasible to make	2	8	4	4	8	8	6	6	6
Total Score		31	27	26	33	38	26	26	28

Requirements	Weight	Phalange Beams	Ironman Glove	Weighted Fingertips	String Weights	Pulley Glove	Motor Grab	Sticky Gecko Glove	Velcro Glove
Makes him feel confident	1	1	2	2	2	1	2	1	2
Easy and intuitive to use	1	3	2	4	3	2	2	4	5
Helps do things that had to be given up	3	9	9	9	9	9	12	9	12
Stabilizes hands when holding small items	2	6	6	6	4	6	8	6	8
Clearly beneficial when using versus not using	1	3	3	3	2	2	4	3	3
Feasible to make	2	6	2	8	8	8	6	8	8
Total Score		28	24	32	28	28	34	31	38

((a)) Jessica's matrix

Requirements	Weight	Spring Glove	Gyroscope Belt	Electrode Patches	Latched Glove	Electromagnet	Buttonpad Guitar	Magnetic Guitar Slider	Arm Beams
Makes him feel confident	1	1	5	5	1	3	3	4	3
Easy and intuitive to use	1	5	4	4	2	3	4	3	5
Helps do things that had to be given up	3	6	6	15	3	12	15	15	6
Stabilizes hands when holding small items	2	6	8	8	2	2	2	2	2
Clearly beneficial when using versus not using	1	3	3	5	1	3	5	4	2
Feasible to make	2	10	8	2	10	6	6	6	10
Total Score		31	34	39	19	29	35	34	28

Requirements	Weight	Phalange Beams	Ironman Glove	Weighted Fingertips	String Weights	Pulley Glove	Motor Grab	Sticky Gecko Glove	Velcro Glove
Makes him feel confident	1	3	2	2	3	1	2	1	1
Easy and intuitive to use	1	5	3	4	3	2	2	5	5
Helps do things that had to be given up	3	12	6	9	9	3	9	3	3
Stabilizes hands when holding small items	2	8	4	8	6	4	2	2	2
Clearly beneficial when using versus not using	1	3	2	3	2	1	1	1	1
Feasible to make	2	10	2	10	10	10	10	10	10
Total Score		41	19	36	33	21	26	22	22

((b)) Elyse's matrix

Requirements	Weight	Spring Glove	Gyroscope Belt	Electrode Patches	Latched Glove	Electromagnet	Buttonpad Guitar	Magnetic Guitar Slider	Arm Beams
Makes him feel confident	1	1	4	2	1	4	1	1	1
Easy and intuitive to use	1	3	4	5	4	4	5	4	2
Helps do things that had to be given up	3	3	9	12	6	15	9	15	6
Stabilizes hands when holding small items	2	4	8	8	4	8	2	2	8
Clearly beneficial when using versus not using	1	2	4	3	2	4	5	5	3
Feasible to make	2	6	2	6	8	6	10	8	6
Total Score		19	31	36	25	41	32	35	26

Requirements	Weight	Phalange Beams	Ironman Glove	Weighted Fingertips	String Weights	Pulley Glove	Motor Grab	Sticky Gecko Glove	Velcro Glove
Makes him feel confident	1	1	3	3	2	2	2	2	2
Easy and intuitive to use	1	2	2	3	3	2	2	5	5
Helps do things that had to be given up	3	9	12	12	12	9	12	6	6
Stabilizes hands when holding small items	2	6	8	6	8	6	4	4	2
Clearly beneficial when using versus not using	1	4	4	3	4	3	5	2	2
Feasible to make	2	4	2	10	6	4	4	6	10
Total Score		26	31	37	35	26	29	25	27

((c)) Colin's matrix

Fig. 8: Individual weighted decision matrices. The team decided on a weight to give each device requirement based on what they thought was most important to achieve, then each member gave a score for the ideas based on how well these were satisfied. Once this was complete, an average score for each idea was produced, as shown in Figure 9.

Team Member	Spring Glove	Gyroscope Belt	Electrode Patches	Latched Glove	Electromagnet	Buttonpad Guitar	Keyboard Guitar	Arm Beams
Jessica	31	27	26	33	38	26	26	28
Elyse	31	34	39	19	29	35	34	28
Colin	19	31	36	25	41	32	35	26
Average Score	27	30.66666667	33.66666667	25.66666667	**36**	31	31.66666667	27.33333333

Team Member	Phalange Beams	Ironman Glove	Weighted Fingertips	String Weights	Pulley Glove	Motor Grab	Sticky Gecko Glove	Velcro Glove
Jessica	28	24	32	28	28	34	31	38
Elyse	41	19	36	33	21	26	22	22
Colin	26	31	37	35	26	29	25	27
Average Score	31.66666667	24.66666667	35	32	25	29.66666667	26	29

Fig. 9: Average weighted decision matrices with the top four ideas. The electrode patches idea would utilize neuromodulation to target the movement cortex and the muscles on the wrist. The electromagnet idea revolved around magnets that could be turned on and off to help the user press/hold the strings. The keyboard guitar created a button based instrument for more ease with the pressing motion. Finally, the phalanges beams idea used rigid beams to limit the shaking motion of the fingers and wrist.

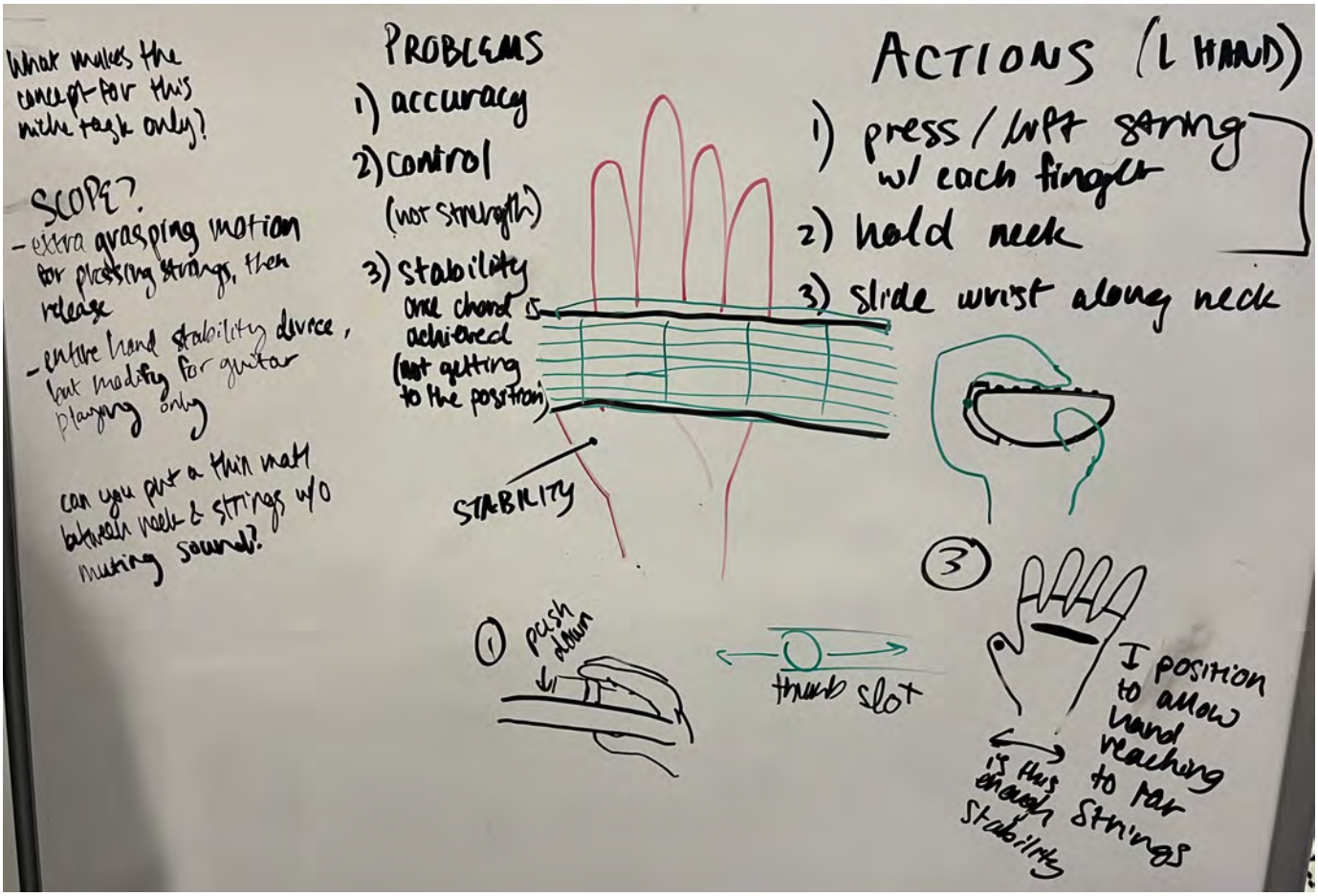


Fig. 10: Whiteboard drawing from team brainstorming session. This session approached the design problem by aiming to address one of three identified problems that individuals with ET face when playing guitar. The concepts generated in this session resulted in a preliminary design to assist the wrist in sliding along the guitar neck, shown in 13.

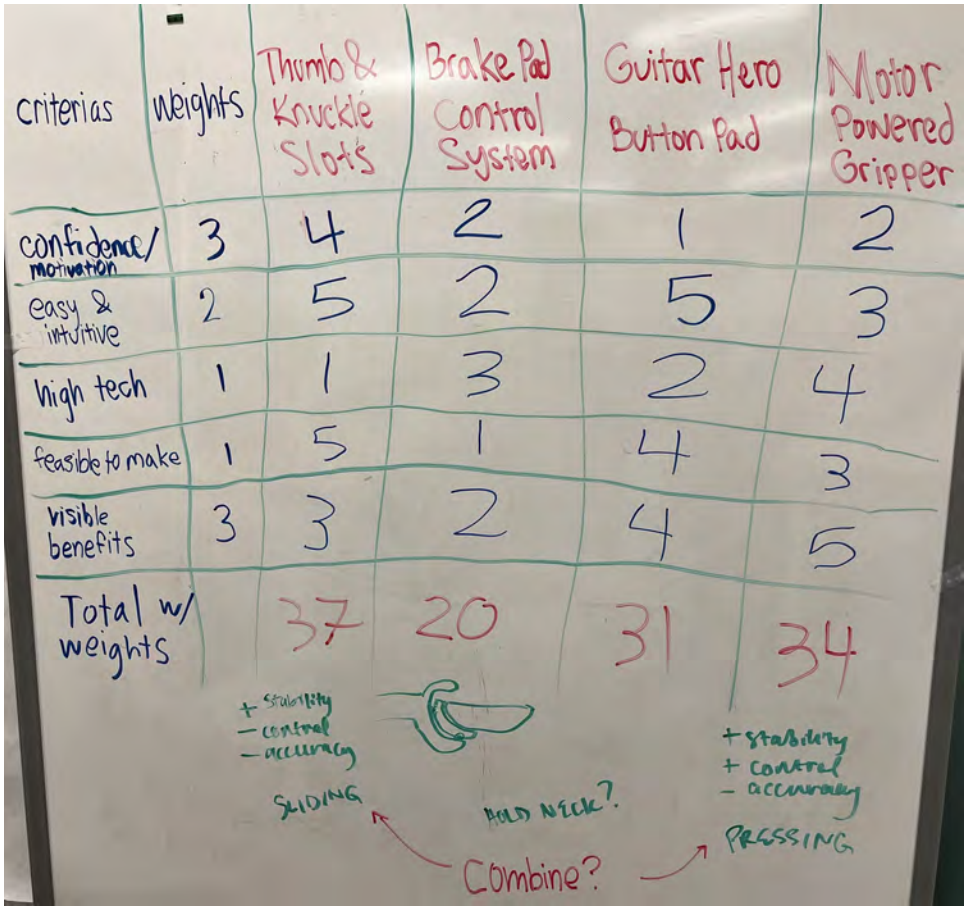


Fig. 11: Second weighted decision matrix to select a more feasible design. This was completed by the team to further refine the possible concepts.

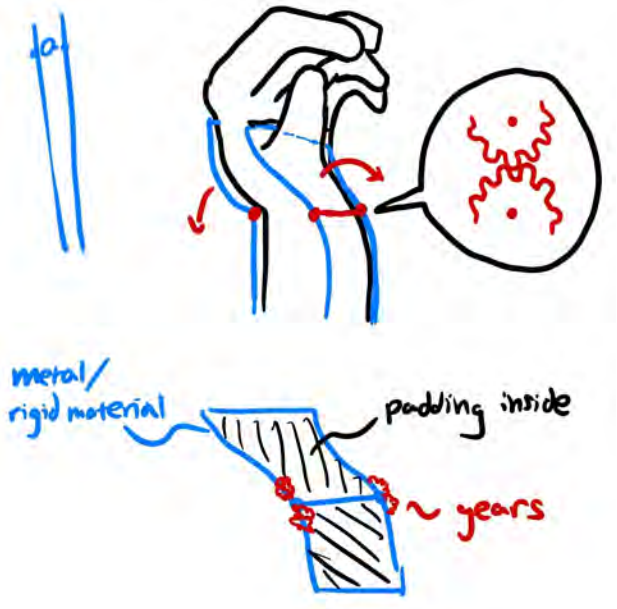
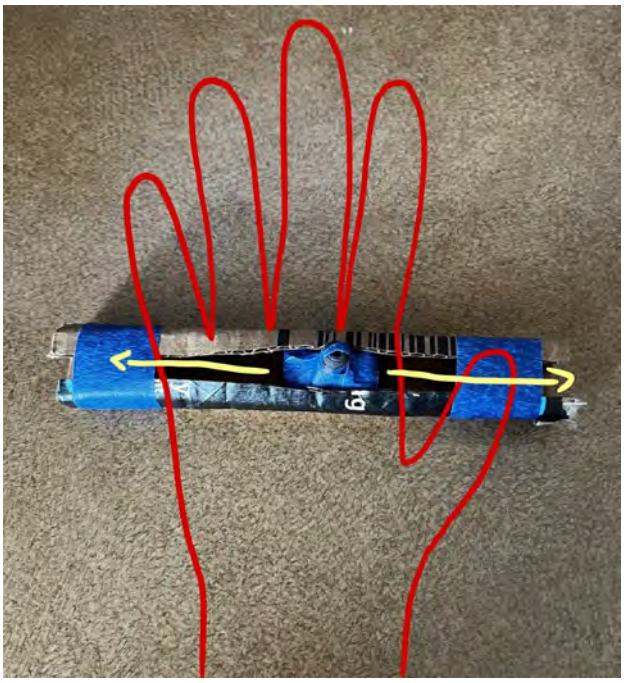
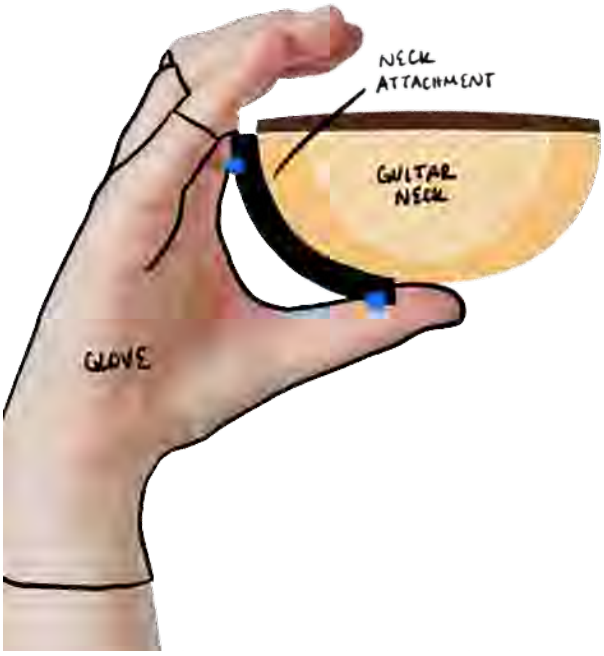


Fig. 12: An early stage sketch featuring gears to limit motion in the flexion/extension direction. A set of metal plates are attached to the forearm, and connected to the metal plates are gears at the ulnar and radial borders. Padding would be added on the sides in contact with the skin to improve comfort.

APPENDIX B
PROTOTYPING



((a)) Top view



((b)) Side view

Fig. 13: The first prototype attempted to create a rail system attached to the neck of the guitar. This would allow the user to slide up and down along the neck while keeping the hand secured. The idea, however, was discarded because the team determined that the user would not be able to reach across the neck with ease when playing complicated chords.

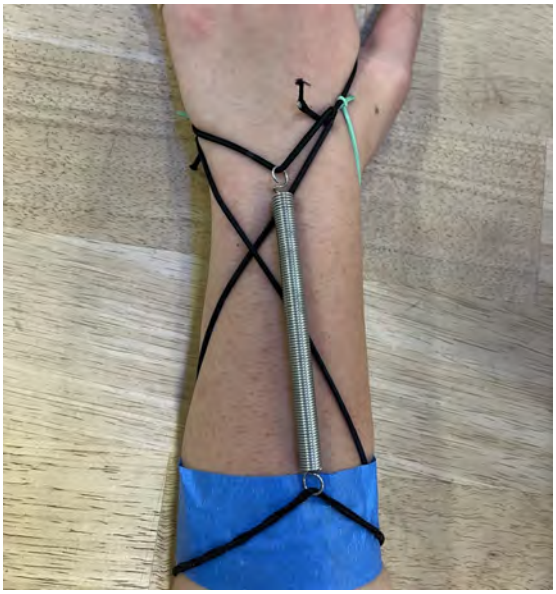
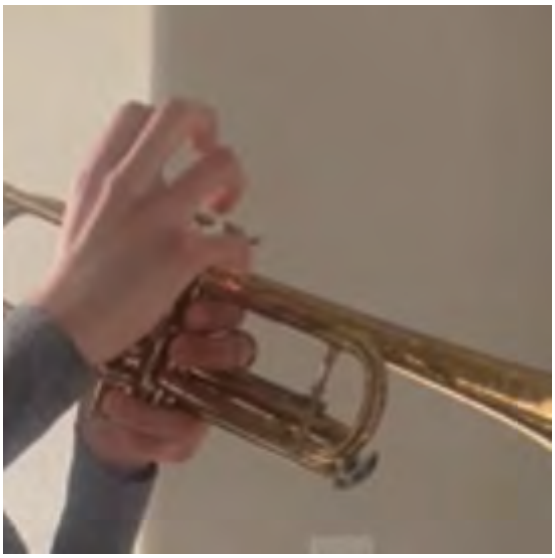
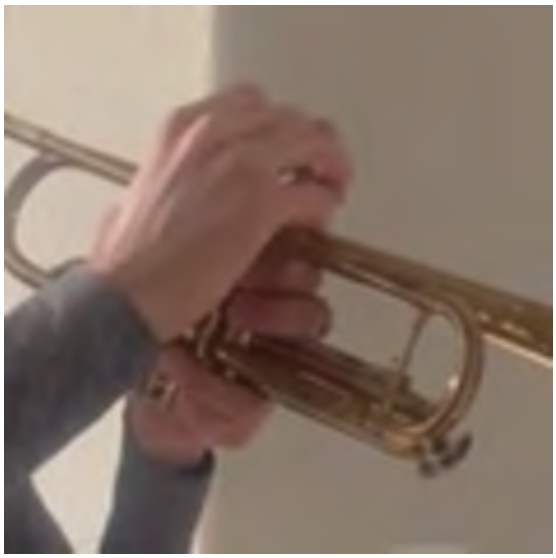


Fig. 14: The team explored a different design that utilized elastic bands and a spring attached near the palmar flexion creases and on the forearm. This was meant to reduce rotational motion along the forearm's axis. This idea did not progress after the team discovered from user observation that most of the shaking from ET was caused in the wrist flexion/extension direction.



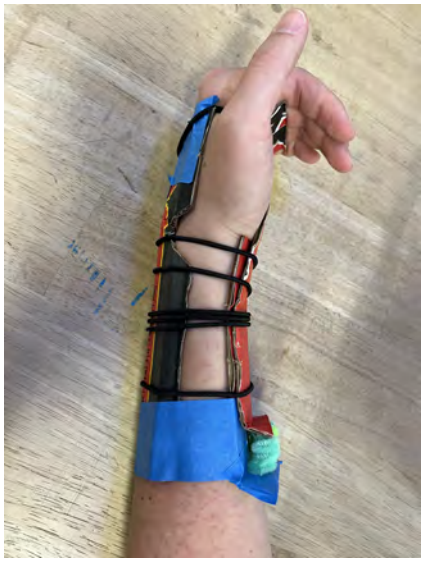
((a)) Not gripping



((b)) Fully gripping

Fig. 15: Screenshots from a video sent by the interviewee playing the trumpet shows what the hand looks like with grasps of varying strength. In situation A, the interviewee does not have a strong grasp of the trumpet, and the effects of ET can be heard through an unintentional wavering of the note being played. In situation B when the grip is harder, the note heard is more steady.

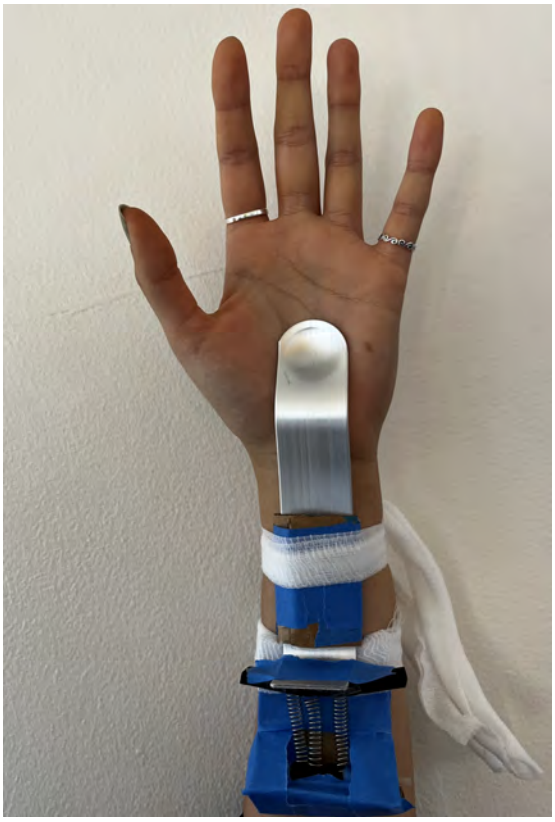
((a)) Top view



((b)) Side view

((c)) Bottom view

Fig. 16: Second iteration of the prototype features a slider that is dampened by springs when pressed down by the shaking motion of the wrist in the flexion/extension direction. The ”springs” used in this iteration were made using pipe cleaners for a low-fidelity approach. Cardboard was used to create ”rigid” components that would slide with respect to each other. Rubber bands and tape were used to secure the components in place.



((a)) Open state

((b)) Closed state

Fig. 17: Third iteration of the prototype is a higher fidelity version that features a metal bar and actual spring mechanism. The metal bar is the removable insert that was found included in a common wrist brace. Gauze was used to secure the components to the wrist.

Fig. 18: Springs and a kitchen sponge were tested as the dampening component of this prototype. The team was interested in evaluating whether springs or a memory foam-like material would produce better dampening.

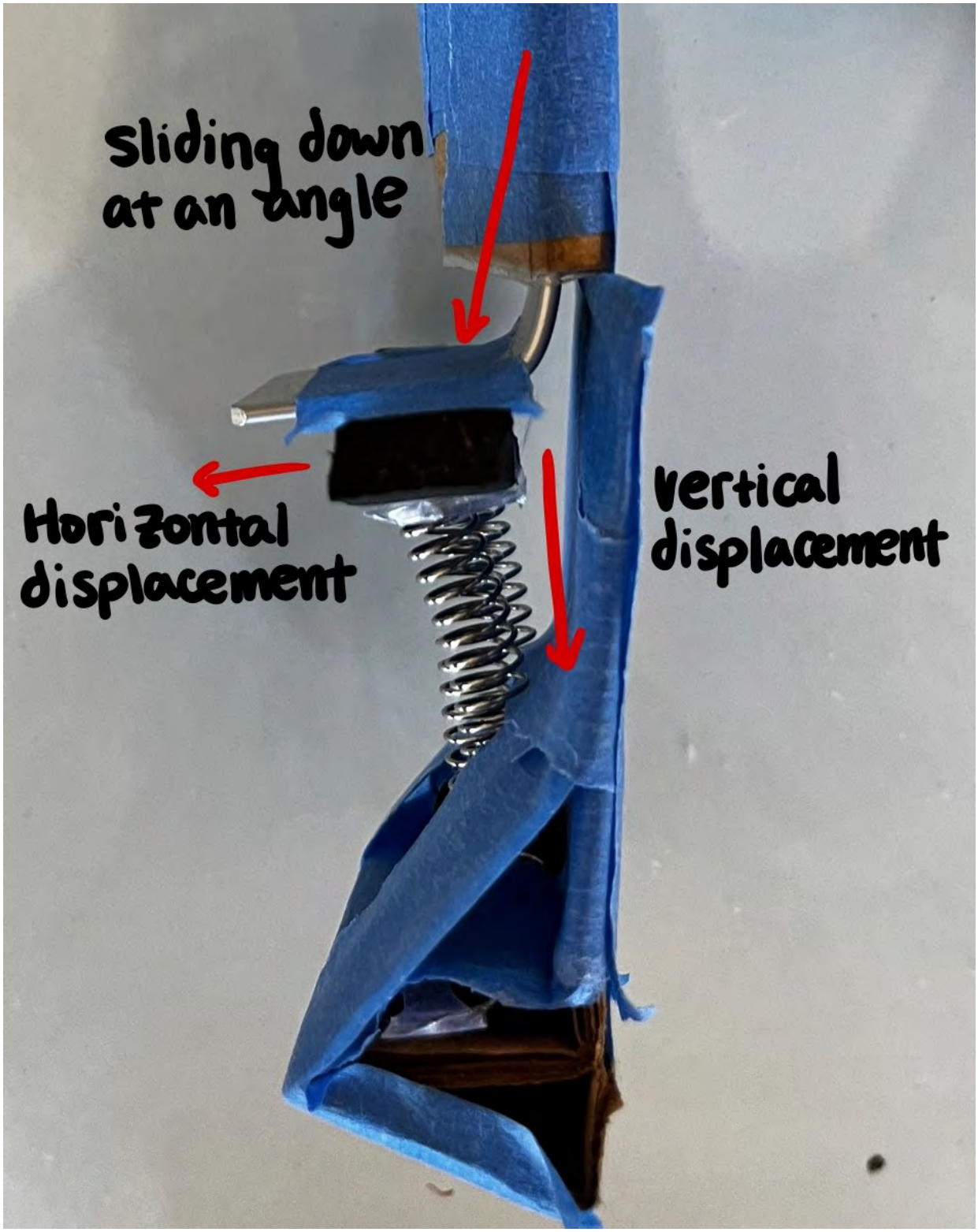


Fig. 19: Testing revealed that the direction of the force applied to the springs during wrist flexion/extension included a horizontal component because the beam movement is rotational as well as vertical. This caused the springs to experience bending in addition to compression. While this was worsened by the springs being longer than necessary, the team considered the shear in the dampening component for future iterations.

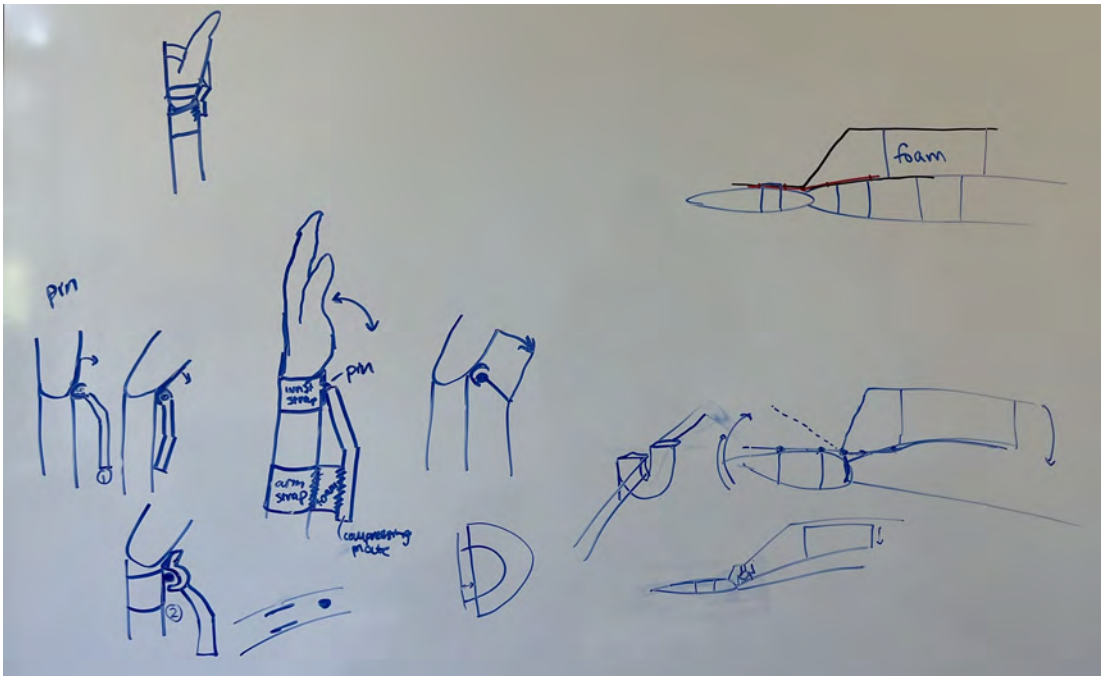


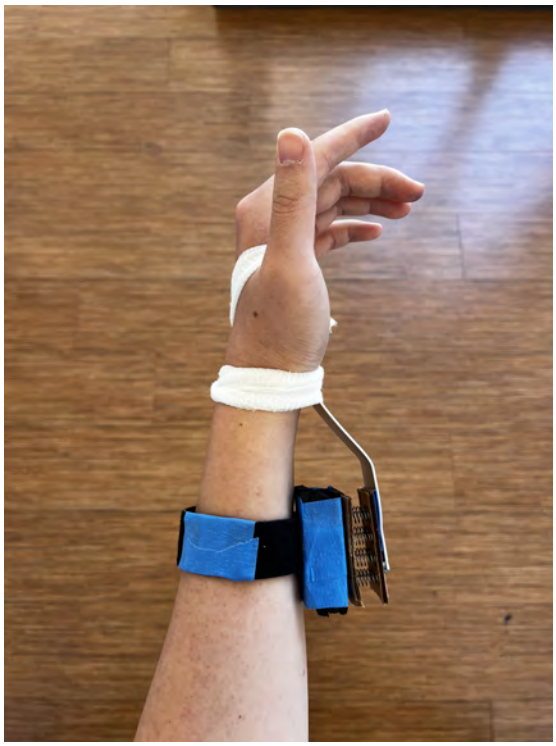
Fig. 20: Sketches considered various geometrical aspects of the fourth iteration of the prototype, such as a more angled metal beam and how it attaches to the wrist. Different joints were considered to provide the degree of freedom needed at the wrist while providing fixation for the device, such as a hinge joint, a ball joint, etc.

((a)) Bottom view

((b)) Side view

Fig. 21: Although memory foam was tested prior to the use of springs, it was determined experimentally that it did not provide as much absorption of the vibration as the spring board.

((a)) Bottom view



((b)) Side view

Fig. 22: This version of the prototype featured a two-by-four array of larger diameter springs. Despite being stable, the team felt that it was too stiff and uncomfortable.

((a)) Open state

((b)) Closed state

Fig. 23: This version of the prototype featured a two-by-ten array of smaller diameter springs. While it felt better than the previous iterations, bending the wrist caused the spring board to shear.

((a)) Bottom view

((b)) Side view

Fig. 24: The fourth iteration of the prototype was a higher fidelity version of the devices found in figures 22 and 23. It replaces the gauze at the wrist with an elastic band and utilizes a spring array found in figure 3.

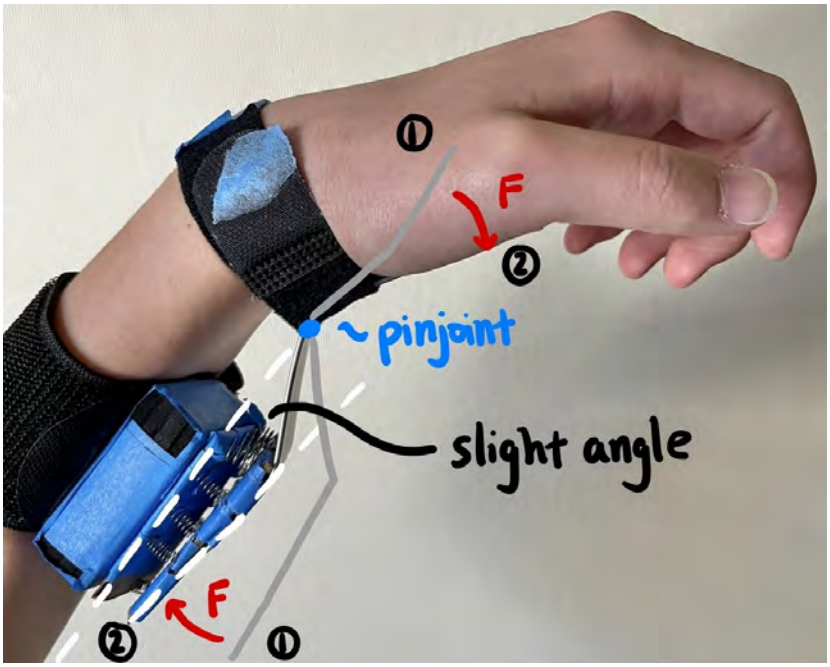


Fig. 25: To decrease pressure and avoid all of the force being exerted along the bottom edge of the beam, the spring board was designed compress at an angle.

APPENDIX C
INVESTIGATIONAL DEVICE DETAILS

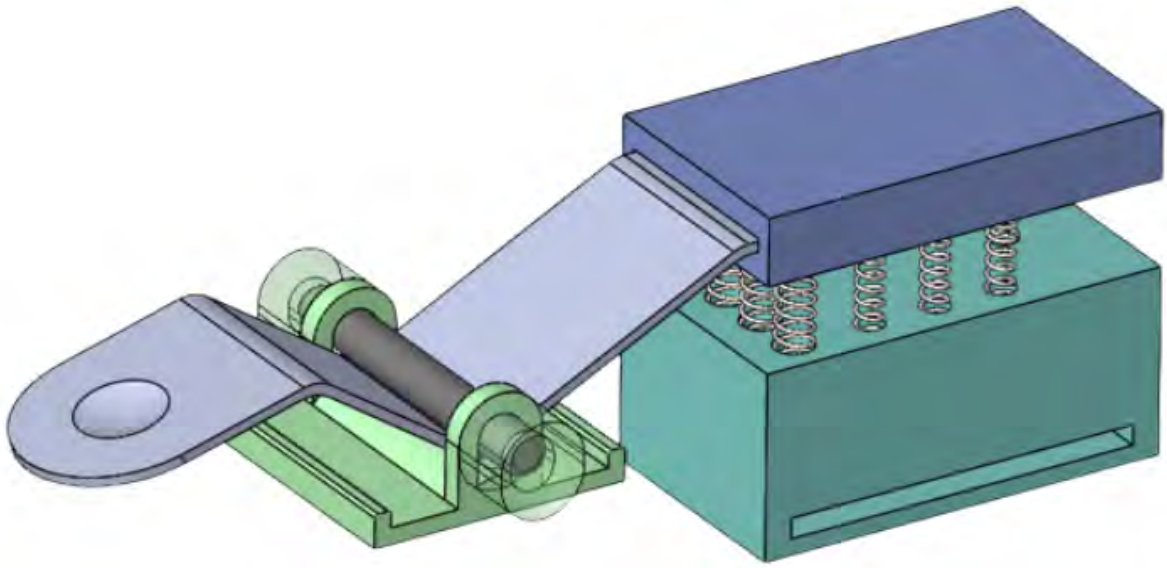


Fig. 26: CAD assembly of DexPlay, which was all 3D printed excluding the metal beam. The metal beam will need to be shaped according to the user's hand shape and size.

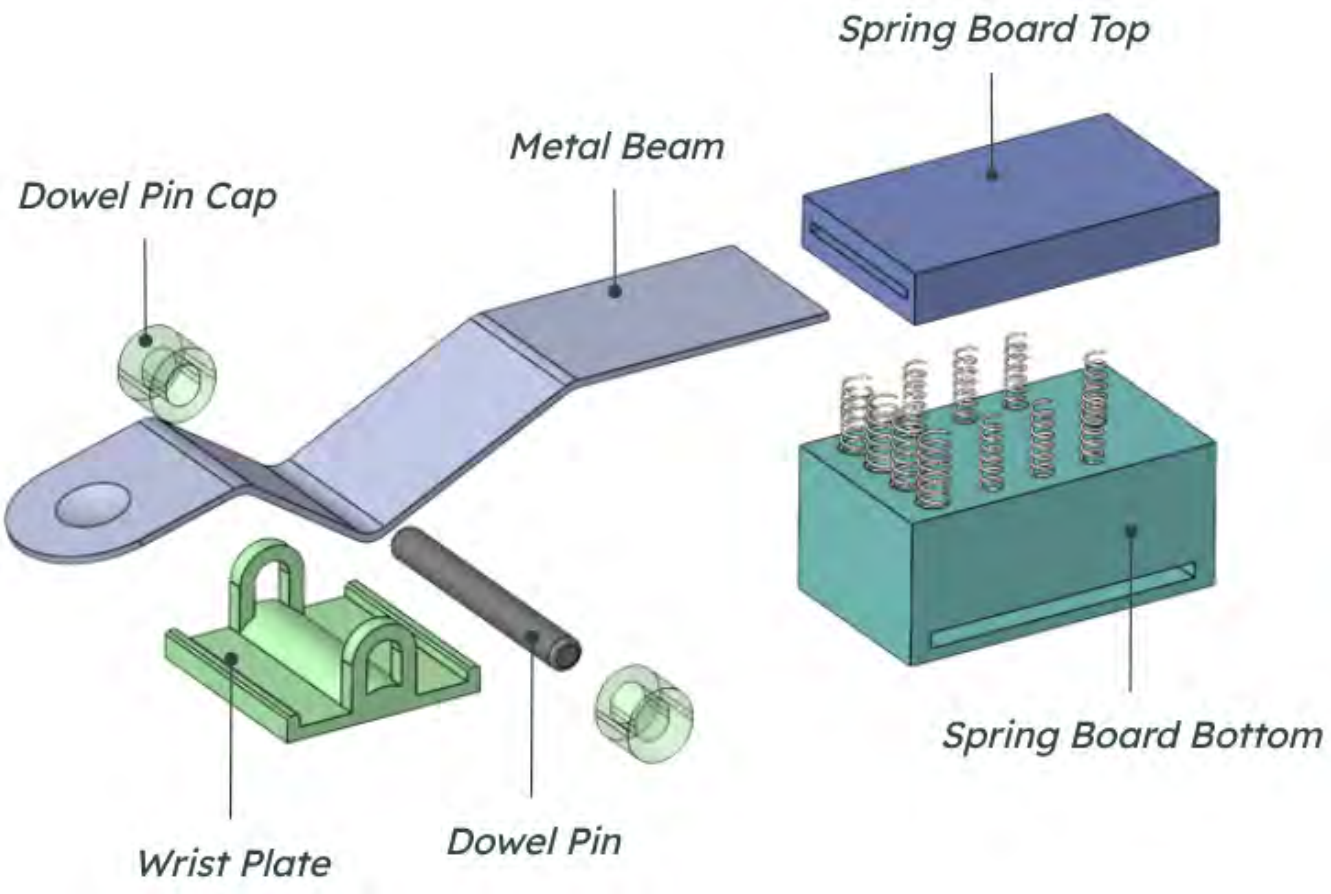


Fig. 27: Exploded view of the DexPlay assembly with labeled parts.

Dex Play

Helping musicians with essential tremors reclaim the ability to play guitar

Limits shaking motion of the wrist by absorbing vibrations

Robin Rockins

Husband and Father

Multi-Instrumentalist

Has Essential Tremors

Identifying A Problem To Address

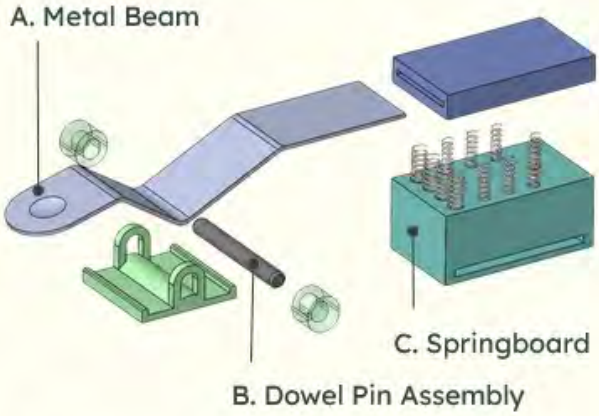
"**I only went so far with acoustic [guitar]** ... the strings are very close together and thin, so it's really hard with tremors to get very good at it."

Determined Needs From Interview

- Wants to **regain** a part of life they gave up
- Wants to feel **confident** around others
- Wants a device making a **real** difference

Simple and Effective Mechanism

1. Shaking motion presses ***A*** at palm
2. ***A*** rotates around ***B*** clockwise
3. ***A*** presses on ***C*** to dampen vibration



Discreet: Audience only sees the two bands that attach DexPlay to the arm

Passive: Purely mechanical design makes device cheap and customizable

Fig. 28: Informational poster created by the team for the Jacobs Showcase.