SoftScribe: Assistive technology to mitigate Writer's Cramp

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Abstract

Muscle and joint pain caused by writing has been an issue in society since writing by hand existed. Studies have been conducted to isolate symptoms and causes of hand cramps and instability, which primarily stem from overly tight grip and poor blood circulation. An interview was conducted to identify the specific needs of people affected by Writer's Cramp, and the resulting data was used to motivate the generation of an assistive device designed to mitigate the effects of this condition: the SoftScribe Pen. Features such as integrated heating and a vibratory warning system were implemented to allow for longer periods of writing without discomfort. Future work is needed to test the effect of heat therapy on other types of hand disorders in order to benefit a wider audience who has reduced hand function.

I. Introduction

As technology continues to improve, writing continues to be an important way humans communicate with others and keep records [1]. However, writing for larger lengths of time can lead to muscle pain and cramping for many. Writer's Cramp (WC) is a movement disorder stemming from long periods of writing that shows effects in the form of unwanted muscle pain and spasms [2]. While the symptoms of this are still an active research area today, plenty of work has been done already to help treat and prevent WC. Writing disabilities have been estimated to affect 10-30% of people in everyday life, and potential solutions are in high demand [3]. This condition lends itself to an assistive device that can help users write more ergonomically and comfortably.

A. Background

While everyone that spends time writing for long periods of time does not develop WC, correlation can be established between pen grip style [4] and total duration of writing, primarily [5]. Studies have also shown that a tight grip on the pen is a symptom of WC [6]. Furthermore, research in kinesiology has informed the decision of ergonomic commercial pens having wider barrels . Based on simple physical reasoning that pressure equals force divided by surface area, having a wider barreled pen helps users not have to pinch down nearly as generic pens. This helps biomechanically in that the writer does not have to recruit as many motor units, or fine muscles, that fatigue quickly and lead to the cramping feeling [7].

Writing utensils on the market currently only have worked to expand the diameter of the pen barrel, along with softening the grip and centering weight [8]. However, solutions preventing writing for large periods of time without rest, and an overly strong grip on the pen are largely missing in the industry. We aim to target users with WC and people who endure levels of pain when writing, or those who want a more ergonomic writing experience. In addition to acting on the work of researchers and making a fully-encompassing device that addresses all of the prior advances in treating WC, we hope to make a contribution to the field as well in the form of heat therapy.

When dealing with lower back pain, continuous, low-level heat therapy is a commonly used tool proven to minimize effects [9]. Heat therapy was also tested on general delayed onset muscle soreness (DOMS) to reduce pain and promote healing to facilitate a return to normal functions. It was found to correlate to an increase in blood flow, metabolism, and elasticity of connective tissues [10]. Heat therapy has not been studied in the hand/wrist region to date, and we believe that the next step to understanding the effects of heat therapy could be testing it on an acute musculoskeletal condition like WC. Deriving from concepts in feedback control theory, a constant heating element in a writing utensil could minimize the "error", or muscle fatigue, and treat it by promoting blood flow and tissue elasticity in the hand/wrist region before the error builds and manifests itself in the form of pain or cramping.

B. Overview

Section II presents the preliminary results we have synthesized after a field interview, from which we gained insights into the primary needs of our interviewee. Before generating the solution concept, we firstly ranked and then highlighted the design considerations that need to be addressed with our device, such as self-sufficiency, restoration of dexterity, plus relief of physical pain. After the literature search, we proposed an ergonomic pen that could effectively reduce crippling hand pain and cramping by incorporating a comfortable grip design and a heating element. We proposed a hypothesis that the addition of heat in the pen increases the duration of writing, as the result of reduced pain.

In section II, we assess the needs of our subject and delineate testing protocols to validate the device's functionality and to justify our hypothesis. We describe our proposed device in III, and later discuss the impact our study could have on the assistive technology community and the broader impact of it to benefit more people with the concerns of hand disorders in section V. The intellectual merit of our device and proposed study is covered in section IV.

II. Interview case study

To understand the needs of a person who suffers from writer's cramps, we contacted an older adult male (age 80+) and conducted a 120 minute interview with him. This interview was conducted in-person at a location where our interviewee spends significant amounts of time in order to observe his daily activities and the objects he interacts with the most. Video and audio recordings were taken for later reference.

Our interviewee is a retired civil engineer, having spent significant time drafting designs using pen and paper, and later using CAD software. This overuse of his hands, as well as previously sustained injuries, have led to difficulties with sustained muscle output during activities such as writing. Specifically, our need-knower expressed that he experiences cramps when writing for long periods of time, as well as shakiness in his hands making it harder to write legibly. One of his favorite pastimes is participating in a letter chain started by his family decades ago. Every few months, our interviewee receives a packet of letters from various family members. He reads through all of them, replaces his old letter in the stack with a new one, then mails all of them to the next person in the chain. Such an endeavor involves writing for hours at a time, which has become difficult for him in recent years. Our need-knower also expressed appreciation for physical activity, and fixing broken objects around the house.

Based on the information we gathered during our interview, we created Table II to motivate our search for an assistive device to mitigate the effects of writer's cramp.

Prompt/Theme	**Interview statement**	**Interpreted need**
Dexterity Issues	"I mentioned if I write a lot that my hand starts to hurt right, cramping."	Product reduces the prevalence/severity of hand cramps
	"I find it hard to get exactly on the right key. So I don't like to do texting."	Product is easy to manipulate finely
	"I think I've verged on carpal tunnel before, when I did a lot of autocad work on a computer which is a lot of detail, you know."	Product reduces strain on wrist
Hobbies	"I think that doing physical things is good for people."	Product involves physical actuation by the user.
Writing Letters	"I don't. I don't know about tremors. It just starts to get shaky, you know. It makes it harder to move the pen."	Product reduces shakiness/instability in hands

III. Proposed Device & Test Methods

A. Proposed Device

The proposed device encompasses dealing with a few of the symptoms found to correlate to WC in previous research as well as adding an investigative element that can contribute to the field.

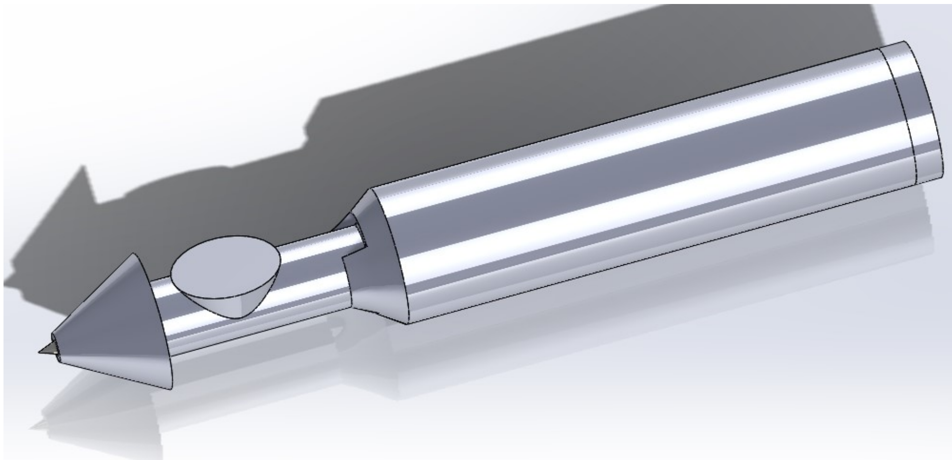

Fig. 1. Pen design

The overall design of the pen is above. At first glance, the exterior is extremely similar to a normal, everyday pen, which is intentional. There are a few major differences, however, the first of which being the large 1 inch diameter. There is a silicone grip around the region where the user will use the device, molded in a specific shape to promote the use of a modified pen grip, a grip style shown to improve WC [4]. Underneath the silicone grip, below where the thumb of the user will be placed, the device features a force sensitive resistor, or force sensor. This force sensor serves two purposes. First, it will be to detect when the user is gripping the pen much too strongly, so much so that it could cause pain, and trigger a vibration motor along the barrel of the pen. Second, the force sensor will be able to measure the time a user has been writing for and provide haptic feedback after a set period of time to notify the writer to take a short break, relaxing their muscles for a small period of time before they get back to work.

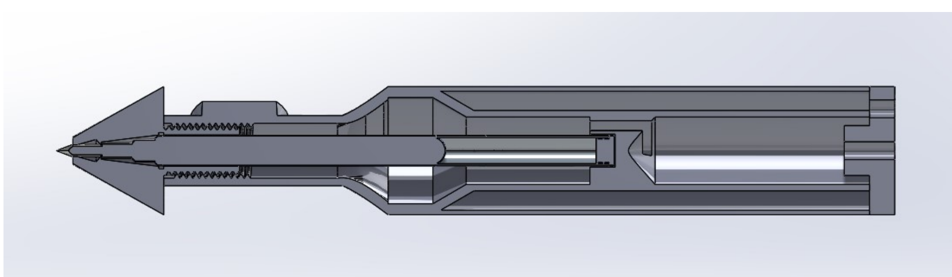

Fig. 2. Pen cross section

The investigative portion of this design comes from the heating element that is incorporated into the upper barrel of the pen. This heating element provides a constant amount of low-intensity heat to the finger and wrist region.

This device will be 3D printed out of PLA for ease of use as well as its favorable thermal conductivity qualities, at 0.13 W/(m*K), which will help minimize the power draw of the heating element and allow more heat to be transferred to the hand. In the future, we hope to explore different manufacturing methods as well as different materials. This heating element will be the focal point of our study, with its location and strength being carefully measured and picked out through testing. Additional detail (like design files for replication along with code ran on the arduino) will be in the Appendix A.

B. Test Methods

To determine the validity of our hypothesis and evaluate the efficacy of our proposed device, we will conduct a study on 10 participants who are affected by writer's cramps. Each participant will complete two trials of transcribing text displayed on a screen onto a separate sheet of paper. This text will scroll across the screen at a constant rate of 40 words per minute, in order to simulate normal writing and ensure consistent writing speed between trials. The trials will end when users experience noticeable pain/fatigue, and the length of the trial will be recorded. The initial control trial will be the same for all participants, and conducted with a Pilot G2 ballpoint gel pen. The second trial will be conducted at a later date to allow for recovery. For this second trial, the participants will be split into five groups of two and given the SoftScribe pen to write with. The power given to the heating element will be adjusted for each of these groups, with even increments from +0°C to +20°C above room temperature provided by the SoftScribe pen. The average time to fatigue/time to pain will be calculated for the control trials as well as for each of the SoftScribe trials and compared.

Because this study involves human subject testing, we will first draft and submit a protocol to be reviewed by the Internal Review Board for the Protection of Human Subjects. All researchers have completed CITI training for Group 1: Biomedical Research Investigators as of May 2023.

Expected Outcomes: We expect to see significant increases in time to fatigue/pain in groups with heated pens. Based on the results of the experimental groups, we will be able to identify an optimal amount of heat to provide in order to reduce cramping. We will also gain an understanding of how to set the time threshold for our vibration warning system.

IV. Intellectual Merit

Our study aims to address the effectiveness of heat treatment on relief for hand cramping. We use a force sensing resistor (FSR) to both give feedback to the vibration warning system and to measure the gripping force. We quantify the duration of pain to gauge comfort level while adjusting the power and duration of the heating pad. Our study results could roughly deduce correlation between heating and improved hand function which is currently a research gap in the field.

The device only addresses the optimal hand and wrist motion. So other parts of the body that are also heavily involved in writing, like arms and shoulder joints could still feel strain and fatigue after a long duration of writing. We can also improve the design by making the heating element respond proportionally to an error term defined by the amount of excessive grip strength applied so that a correlation between heat needed to be applied and grip strength could be established through studies.

V. Broader Impact

Ergonomic pens have been one of the most well-known assistive devices that aid to reduce pain and improve writing efficiency. For elderly population who are more prone to a reduced hand function and Writer's Cramp, an ergonomically designed pen is more comfortable to use because it exerts less physical force on the hand's tissues. It has been proven by many studies that ergonomic pens can reduce wrist and hand musculoskeletal injuries, limiting Writer's Cramp, as well as carpal tunnel syndrome and arthritis. Our device not only provides comfort for writing, but also incorporates other features such as heat treatment and vibratory warning. So future work could be done to investigate the effect of heat treatment on other hand disorders. If it is proven effective, our multiplex device could be replicated and adapted to provide more populations with pain relief caused by other conditions while maintaining comfort and portability.

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APPENDIX A
INVESTIGATIONAL DEVICE DETAILS

Fig. 3. Final Prototype

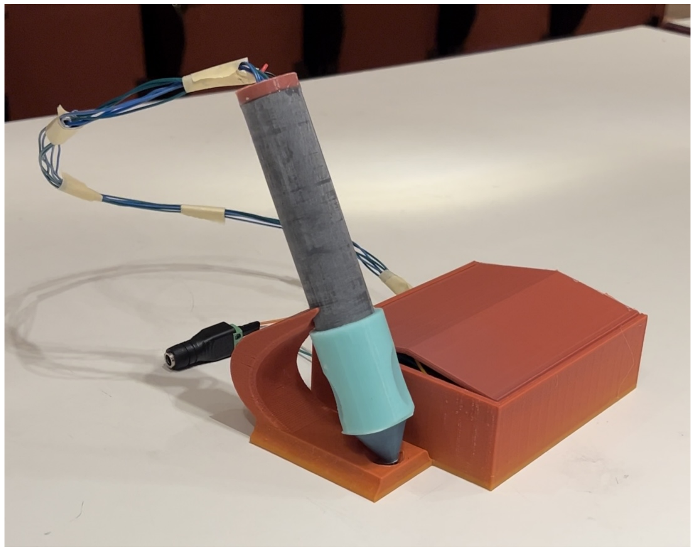

Fig. 4. Final Prototype open box

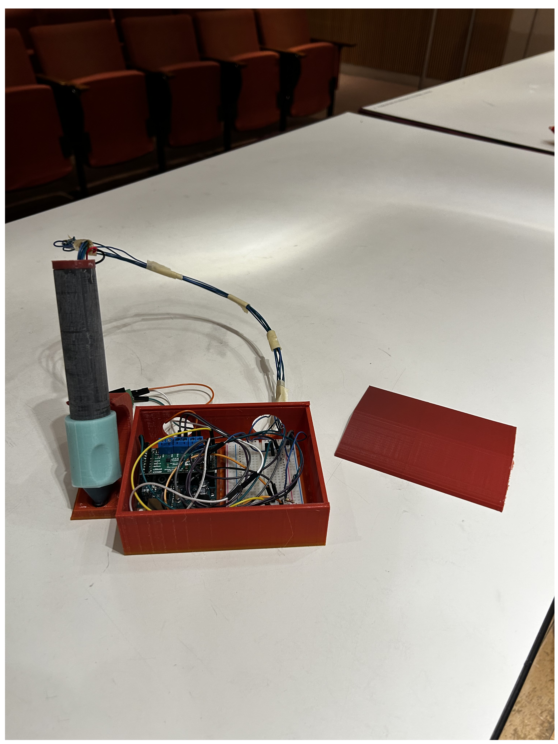

Fig. 5. Code run on Arduino Pt. 1

```
int thresh = 175;
int low = 150;
int high = 200;
float val = 0;
int state = 0;
unsigned long prev = 0;
int s = 0;

void setup() {
  #define signalPin A4            //sensor output pin

  Serial.begin(115200);
  millis();
  prev = millis();

}

void loop() {
  // put your main code here, to run repeatedly:

  analogWrite(9, 100);

  val = analogRead(signalPin);
  //Serial.println(val);
  if (state == 0) {
    if (val>high) {
        state = 200;
        analogWrite(3,70);
    }
  }

  if (state == 200) {
    if (val<low) {
        state = 0;
        analogWrite(3,0);
    }
  }

  unsigned long x = millis()-prev;

  if(x>10000 && x<12000){
    s = 1;
  } else {
    s = 0;
  }
```

Fig. 6. Code run on Arduino Pt. 2

```
  if(x>12000) {
    prev = millis();
  }


  if(s ==1) {
    analogWrite(3,70);
  }

  if(s==0 && state == 0){
    analogWrite(3,0);
  }


  //Serial.print(val);
  //Serial.print(",");
  Serial.print("FSR ");
  Serial.println(analogRead(A4));
  Serial.print("Millis ");
  Serial.println(millis());
  Serial.print("prev ");
  Serial.println(prev);
  //Serial.println(state);
  delay(100);


}

```