Project Group 2 - Lowered Dexterity in Gaming

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Augmenting Human Dexterity – Spring 2021

Term Project Report

Abstract

This paper details the design and experimentation of a glove tailored to the needs of a PC gamer. Gaming performance can decrease due to cold hands. The decrease in performance can be attributed to decreased dexterity due to low blood circulation in cooler environments, as supported by both a literature review and an interview with a casual gamer. This glove is innovative in its design of multiple materials and modularity, with an FIR material proven to increase blood circulation, parafricta material for ease of use on desks, and reusable/removable heat packs. Testing of the glove comprises testing subjects that are exposed to a variety of conditions and measuring their Actions-Per-Minute (APM) to measure the effectiveness of the glove's design. The glove design can possibly be used in a variety of settings that need to maintain manual dexterity simultaneously with keeping the user's hands warm such as an office.

I. Introduction

Our team was inspired by a recreational gamer who experiences frustration when his performance decreases with cold hands. He needs a solution that allows him to retain his hands' fine dexterity and thermal comfort at a cool room temperature. There are more than 100 million registered PC game players in the U.S. in 2019 before the COVID pandemic further boosted the gaming industry [1]. Coldness and stiffness of hands are common concerns that impact gaming performance and diminish their gaming experience. It can be a result of a cold environment, sedentary lifestyle, or medical conditions such as anemia and thyroid imbalance. The existing solutions either sacrifice hand movement or neglect thermal comfort. The solution proposed in this project is expected to increase the user's gaming performance and reduce anxiety caused by hand coldness in his recreational activity. This solution which retains most hand dexterity while ensuring hand comfort can be valuable to gamers, typists, and other audiences who need full hand dexterity in their daily lives.

A. Background

The hands' proper functionality is defined by various parameters including reaction, sensitivity, velocity, mobility, and force [2]. For PC gamers, the finger's speed and accuracy of controlling the keyboard and mouse are particularly important. These factors are in turn influenced by environmental conditions, including low ambient temperatures [3][4]. To maintain a constant core temperature, the human body's thermoregulatory system reacts to the cold environment by decreasing blood flow to limit heat loss [5][6]. The ambient temperature and the reaction mechanisms that impact manual and finger dexterity are studied by researchers for various purposes.

Hand skin temperature and core temperature are monitored for studies aiming to model their relationship with hand dexterity. Wang et al. found that the subjects' hands are the most comfortable among the five temperature conditions when the ambient temperature is at 78 °F [7]. Furthermore, they found that the hands retain optimal dexterity and maximum comfort when the finger temperature and hand temperature are between 88 °F and 95 °F. On the other hand, Schieffer et al, McCleary, Hellstrom, and other researchers all found that decreases in finger dexterity start to be observed when the hand and finger skin temperatures are below 75 °F [8], [9], [10]. Significant losses of hand dexterity are observed at a local skin temperature of 60 °F and below [8], [11], [12].

To overcome the loss of dexterity in a cold environment, engineers proposed and tested solutions from three main categories: passive, direct, and indirect hand heating [13]. Traditional passive solutions include

layering textiles to entrap air in between and therefore limit convection. As a result, most of these solutions can hardly maintain the original body mobility due to their cumulative thicknesses [6]. A solution that involves innovative material is far-infrared textile. The high infrared emissivity of far infrared textiles is achieved by combining inorganic powders with fabrics [14]. They absorb energy from sunlight or the human body and release infrared rays with an 8 to 12m wavelength back to the human body. Far infrared ray is proven to have medical benefits including improving local blood circulation by expanding capillaries and inducing heat generation through resonance [15].

Direct and indirect heating of hands is often compared for their performance in maintaining hand dexterity in cold. Direct heating is achieved by electrically or chemically heated gloves. Indirect heating involves supplying heat to other body parts such as the torso, forearms, and feet. Brajkovic and Ducharme studied the difference between hand heating and torso heating on dexterity [16]. In their experiments, subjects wearing hand or torso heating garments were exposed to a -13 °F environment for 3 hours while monitoring finger and forearm skin, as well as muscle temperatures. They are then asked to complete the C-7 rifle task and Purdue Pegboard (PP) as the dexterity test. They concluded that the resultant finger dexterity and skin temperature are comparable between direct and indirect hand heating despite an increase in finger blood flow with indirect heating.

A strong correlation between blood circulation and hand dexterity is observed in studies that do not maintain proximal skin temperature [17], [18], [19]. And indirect hand heating is believed to have an advantage over direct heating in improving blood circulation. Moreover, LeBlanc found that keeping the hands warm is not enough to maintain finger dexterity if forearm muscle temperature is low (below 86 °F) [20]. However, supplying heat to distant body parts consumes more energy than direct hand heating in keeping peripheral skin temperature [21]. To maximize indirect heating's benefit, Kosch found that, among the different body parts, warming up the arms is the most energy-efficient in increasing blood perfusion [22]. A study by Castellani et al. also found that the power required by increasing arm temperature is less than that for the torso to achieve the same hand dexterity improvement [23].

The effectiveness study of the different solutions led to a conclusion that the most critical factor in keeping hand dexterity in cold environments is normal peripheral blood circulation. The blood circulation can be improved by increasing hand temperature through either direct or indirect hand heating. However, no device is optimized for hand dexterity needed for PC gaming. The finest hand dexterity test conducted in the experiments is pin insertion which can not be used to evaluate PC game performance. Thus, this study will focus on designing a device that increases hand skin temperature and thermal comfort while retaining full finger dexterity for PC gaming. The gaming performance related to finger dexterity will be measured through an action-per-minute (APM) test, scored by the number of correct key activation of keyboard and mouse in a minute, which is frequently used in the e-sport industry to evaluate a player's skill.

B. Overview

According to the background research, examined in *Section I-A*, hand skin temperature is proportional to local blood circulation which is the major factor for hands to retain normal dexterity. We hypothesize that increasing the skin temperature of hands and forearms improves the user's APM measure and enhances the user's self-reported satisfaction with their gaming experience. The preliminary interview with a young adult who is an avid gamer, discussed in *Section II*, supports the research findings, which allowed us to design a glove device that specifically meets the needs of gamers, as well as office workers who experience lowered dexterity. *Section III* shows the four main features on the device, including the fingerless glove design, FIR glove material, reusable chemical heat pack, and a near-frictionless Parafricta material. The effectiveness of this design will be tested following the methods mentioned in *Section III*. If the hypothesis stands true, further investigation might be needed to confirm the effectiveness of the device in different environments, as discussed in *Section IV*. Furthermore, if the results of the finders are convincing, the glove's design can be slightly altered to fit the need of other professions, examined further in *Section V*.

II. Preliminary Results

The interviewed need-knower is from the 18 to 34 age demographic which is the biggest age group among all the U.S. PC gamers [24]. Gaming is an important daily stress-releasing activity for him but cold hands largely impact his experience. The interview intends to discover the actual needs of the interviewee during gaming. A Zoom interview was scheduled at the time when the need-knower would normally start gaming. By this means, he was able to walk the team through his typical experience and recalled specific details that were essential to the study.

The interview focused on four topics: general information of the interviewee, setup and preparation for gaming, gaming experience including any discomforts, and current remedies for the discomforts. The first two topics help us understand the environment that the future solution will operate in. The latter two topics reveal discomforts that need solutions and factors that can be improved. Techniques used in the process include asking follow-up questions to describe current experiences and solutions, repeating the last words to confirm the interviewee's answers and the power of silence which allowed the interviewee to divulge more details.

We identified 33 needs from the interviewee's statements, from functionality requirements to size and energy constraints. The five most important requirements are listed in the table below in order of importance:

Customer Statement	Interpreted Need
I use my current setup for many other purposes and have no complaints. I do not have plans to change anything.	The solution operates normally in the current environment.
For my right hand, I click quickly with my index finger. For my left hand, I use all of my fingers. Speed and accuracy are equally important.	The solution maintains the full dexterity of both hands.
Sometimes I notice my hands get cold and start to be anxious about performance. The feeling makes me uncomfortable.	The solution keeps both hands warm.
I cannot stop in the middle of a game, which can last as long as one hour.	The solution operates consistently during the gaming period (60 min).
Gaming is a hobby to me, I am unlikely to pay a lot unless it can be used for more than gaming.	The solution requires little investment or has multiple use cases.

Fig. 1. Top 5 Requirements Derived from Need-Knower Statements.

The interview revealed the two most valued traits of the solution which are economic efficiency and effectiveness in increasing performance.

The interviewee plays PC games almost every day during the evening for 2-3 hours. Although he enjoys a cool room temperature throughout the day, his hands get cold during gaming. Cold hands slow down his finger movement, especially his right hand's index finger used for left-clicking the mouse. In addition, the accuracy and speed of his left hand controlling the keyboard are affected. Aside from gaming performance, the interviewee expressed that it's unpleasant to have cold hands during gaming even if the specific game doesn't rely on finger dexterity. Therefore, maintaining the hand's dexterity to ensure performance and keeping hands warm for psychological comfort are equally important measurements for the solution's effectiveness. Another determining feature of a solution constrained by his current gaming habit is the continuous functional length. Most of the games he plays are multiplayer strategy and fighting games that cannot be paused in the middle and usually last from 30-60 minutes. As a result, the solution must be

effective throughout one game if not the complete gaming period of the day. The interviewee uses his work desk with a PC and two monitors for gaming. The table is fully occupied by notebooks and other electronics, leaving minimal space for a device to increase local ambient temperature. The area between the monitor and the user is reserved for the keyboard and the mouse-pad. The user is unwilling to make any major modifications to his current desktop setup.

The user's current solution for cold hands is wearing a sweater. It can be considered as indirect and passive hand heating by limiting body heat loss. With the sweater, he keeps his hands relatively warm but the sweater sometimes makes him excessively feel hot in the torso area. Thus, he maintains a relatively low AC-controlled room temperature (65 °F) which undermines his efforts to keep his hands warm. In addition, he complained that the sweater slightly decreases the flexibility of the elbows. However, the downsides of wearing a sweater do not disqualify it from being the most used solution for the interviewee because of its economic efficiency. The user also mentioned that gloves are not used because covering the fingers is uncomfortable and impacts his clicking accuracy significantly. The interviewee considers gaming as a hobby which limits his budget for a performance-increasing solution. Therefore, the team valued low-cost concepts and multifunctional concepts higher than others during the device design process.

III. Methods

The proposed device is a pair of fingerless heating gloves utilizing a multi-layer approach to achieve both thermal insulating and blood circulation inducing functionalities. The layer in contact with the hand and arm skin, indicated in red in Figure 1, is made of far-infrared textile for blood flow improving [25]. The next layer is placed from the base of the palm to the forearm indicated in green in Figure 1. This layer is made from a material with a low coefficient of friction, known as Parafricta, allowing the arm to glide effortlessly on the desk [26]. The glove will increase the hand's skin temperature through a thin, flexible, and removable heated pad placed at the back of the hand, represented in the color blue in Figure 1. The sodium acetate solution inside the heat pad will solidify and release heat during its crystallization process after activation [27]. This pad can be reused by reheating to reverse the crystallization and return to the original liquid state [27]. The device prototype is presented in detail in Appendix A.

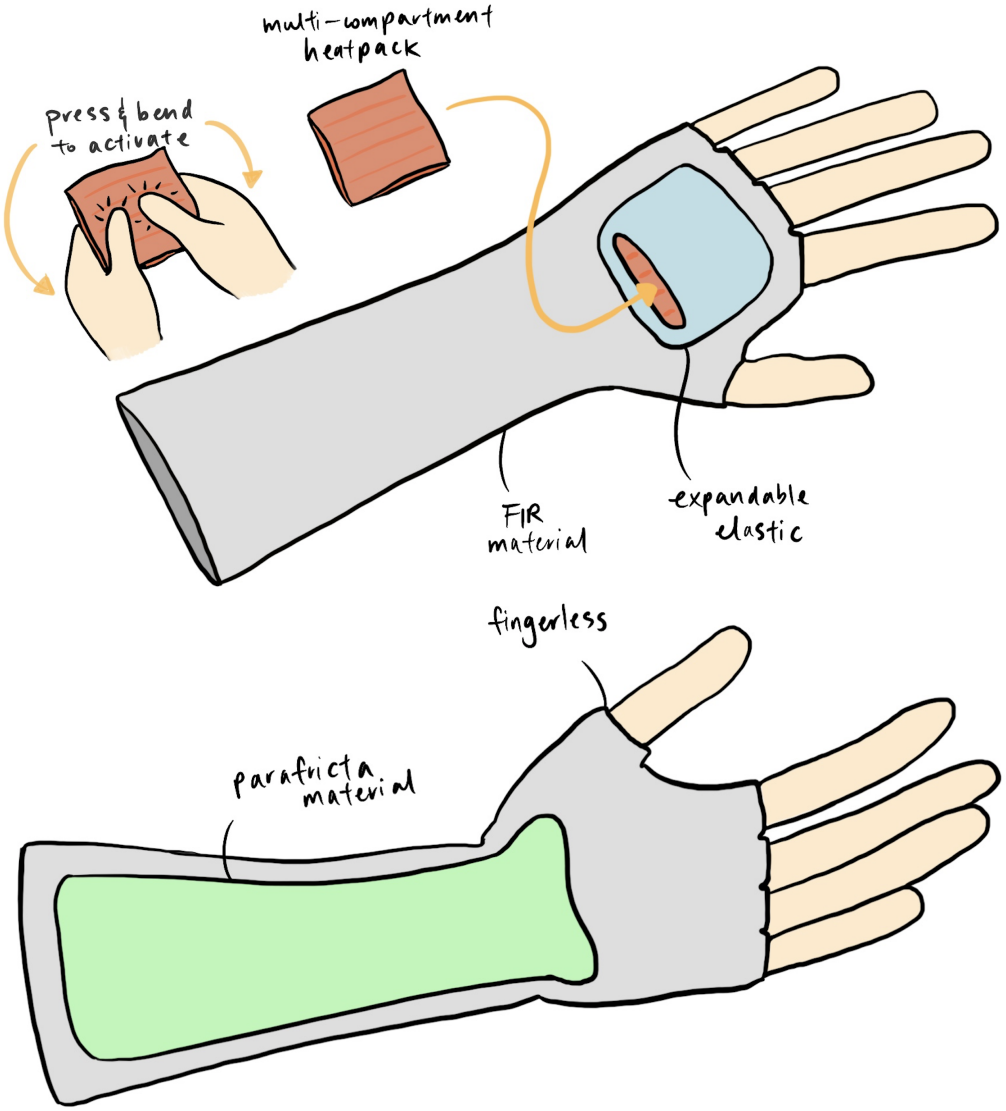

Fig. 2. This is an illustrated concept of the glove.

The objective of the tests is to test our hypothesis that wearing the proposed device will increase the hand's skin temperature and therefore improves the user's gaming performance and experience in a cool environment. We will recruit 3 females and 3 males who are between the age of 18 to 34 and play PC games more than five times per week. Their finger dexterity will be evaluated by APM measured using

testing software on PC. The testing software will assign different commands to keys on the keyboard and mouse. During the test, the command will be shown on the screen and the subject is required to click the associated key after seeing the command as fast as possible. The subject gets scored based on the number of correct input commands in the limited time. Maximum APM is normally required for no more than one consecutive minute during games. Therefore, each APM test will be one minute in this study. The gaming experience related to finger dexterity will be measured through the subject's self-reported satisfaction level of their performance in the APM testings on a scale of 0-10 with 10 being the highest.

The subjects will be tested in rooms with an air conditioner, room thermometer, and one PC with a keyboard and a mouse. Thermocouples monitoring skin temperatures will be attached to 10 places on the subject's skin: index fingers, palms, back of the hands, and both the inner and outer sides of the arms. Subjects wearing a short-sleeve t-shirt and long pants will be placed under four conditions:

	Low Skin Temperature (60 °F to 75 °F)	*High Skin Temperature* (> 88 °F)
Cool Room (65 °F)	Condition 1	Condition 2
Warm Room (75 °F)	Condition 4	Condition 3

Fig. 3. Four Testing Conditions

As the Background section mentioned, the subject is expected to have noticeable loss of hand dexterity when the hand and arm skin temperatures are between 60 °F to 75 °F which is referred to as low skin temperature in the test conditions. On the other hand, the hand is the most comfortable with optimal dexterity with skin temperatures above 88 °F. The cool room has a room temperature of 65 °F which is the need knower's preferred room temperature. The warm room temperature is set to be the most comfortable temperature for the thermal comfort of hands as discussed in Background.

The test procedure consists of five stages as described below. The sequence of tests under Condition 1-4 is determined so that the minimal activity level of the subject is required. To further mimic PC gamer's sedentary behaviors, the subject will sit in front of the testing hardware for at least 10 minutes while preparing for the first APM test of the stage. During each stage from Stage 2 to 5, one testing process is referred to as a one-minute APM test, a self-reported satisfaction level questionnaire, and a two-minute break if it is not the last test in that stage.

I	Preparation (*Cool Room*)	The subject will enter the *cool room*, keep seated and get familiar with the keyboard, mouse, and the APM testing software. Test subjects will practice using the hardware and software for 30 minutes.
		The subject is ready to start Stage 2 once they achieve consistent APM test scores, to be specific, the subject needs to have three consecutive APM tests where the difference between scores is within 10% of each other.
II	Condition 1 (*Cool Room*)	In the *cool room*, the test subject will immerse their hands into 60 °F water until all of the measured skin temperatures are below 75 °F.
		The subject will repeat the testing process three times and immerse his/her hands into 60 °F water again in between tests if the skin temperature is above 75 °F.

III	Condition 2 (*Cool Room*)	The subject will stay in the *cool room*, put on the heating gloves, and wait until all the measured skin temperatures stabilize above 88 °F.
		The subject will repeat the testing process three times with skin temperature maintained higher than 88 °F.
IV	Condition 3 (*Warm Room*)	The subject will remove the heating gloves, enter the *warm room*, and wait until all measured skin temperatures stabilize above 88 °F.
		The subject will repeat the testing process three times. If the skin temperature is below 88 °F, the subject will immerse their hands into 105 °F water to increase skin temperatures.
V	Condition 4 (*Warm Room*)	The subject will stay in the *warm room* and immerse his/her hands in 60 °F water until all of the measured skin temperatures are below 75 °F.
		The subject will repeat the testing process three times and immerse his/her hands into 60 °F water again if the skin temperature is above 75 °F.

Fig. 4. Five Testing Stages with Two Sub-stages for Each

For each participant, both the APM measure and satisfaction level with high skin temperature, Condition 2 and Condition 3, are expected to be significantly higher than those with low skin temperature, Condition 1 and Condition 4. With low skin temperatures, the subjects may experience faster increase in skin temperatures in the warm room than in the cool room. As a result, APM scores may be slightly higher for Condition 4 than Condition 1 and the subject may be asked to cool hands in cold water more frequently. The difference of the APM measures among all participants under different conditions will not be compared, as each participant can have drastically different skill levels in keyboard and mouse control. However, the average APM and satisfaction level among all participants are expected to be the lowest for Condition 1, the second-lowest for Condition 4, and comparable for Condition 2 and 3.

IV. Intellectual Merit

The proposed experiment tests whether the theorized device is capable of maintaining a user's APM while under cool room conditions. With the results of this experiment, the efficacy of the device in realistic settings would later need to be determined and will lead to the investigation of the device during more unconstrained gameplay. This gameplay experiment would entail having subjects that describe themselves as being skilled at a specific game and possibly running timed trials to perform certain objectives. The temperature conditions can mirror the ones mentioned in our experiment. More research into extreme conditions like freezing temperatures and the therapeutic effects of using FIR in the glove is also possible. Although FIR has been studied and shown to have therapeutic effects, more research needs to be done on the extent of these effects on conditions like carpal tunnel syndrome that are prevalent in people who extensively use a computer.

V. Broader Impact

We expect our device to have positive outcomes for gamers who want to perform at their best in cold environments. This investigation focused on a niche area of gamers who play PC and their performance decreases because of a cooler environment decreasing their dexterity. This glove's material properties allow

for the use of the gloves in a broader setting. Due to the material's therapeutic effects and the maintained dexterity while wearing the gloves, the glove can be used in a variety of settings which include but are not limited to the office and working in colder environments. All these settings and more require a maintained dexterity while operating in cooler environments which the glove is designed for.

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APPENDIX A
INVESTIGATIONAL DEVICE DETAILS

Fig. 5. Testing for glove model that retains full dexterity.

Fig. 6. Testing the heat pack size/shape so that it does not interfere with dexterity.

Fig. 7. Testing for need of palm tactile sensitivity and potential attachments to fingerless glove.

APPENDIX B
REQUEST FOR INTERVIEW SCRIPT

A. Invitation Email

Dear xxxx,

Hi, we're a student project group from University of California, Berkeley. In our Augmented Human Dexterity class, we're learning about assistive technologies that can improve the performance of hands and arms.

We're reaching out to you because we heard from Samantha that you are a need-knower who might be interested in participating in our study on gaming in cold environments.

We would like to explore possible solutions for this topic, and we're hoping to schedule a 1-1.5 hour interview with you to discuss your experience. The interview will focus on your interaction with controllers, keyboard or mice in cold environments, and the material gathered from the interview will not be shared with anyone outside of the class. We will also keep identifiable information private (not released to public nor class).

Please understand that the interview is for discovering a potential need and we will not be able to provide any compensation for your help. However, we would be more than happy to share our findings with you if you decided to participate.

Please do not hesitate to let us know that you are not interested. Feel free to reach out to us through email if you have any concerns or questions. Thank you for your time and consideration.

Best regards,
Samantha Yang

B. Accept Email

Dear xxxx,

Thank you for your reply! Just as a reminder, we're a student project group from University of California, Berkeley. We reached out to you for an interview regarding your gaming experience. Thank you for allowing us to interview you as part of our class project.

We would like to set up a Zoom interview for next week. If you prefer something other than Zoom just let us know. What time would work the best for you between March 1 to March 7? We would like to reserve 1.5 hours with you and the interview will not exceed the scheduled time. Please provide at least 3 time slots if possible. We will try to set up the interview time at your preferred time.

Thanks again for helping with our project. Please feel free to contact us if you have any concerns or questions. Also, please do not hesitate to let us know if you will not be available for an interview next week or in the future.

Thank you!
Samantha Yang

C. Reject Email

Dear xxxx,

Thank you for replying to this email. We really appreciate your time and consideration. We completely understand your decision to not participate in our study.

Thank you!
Samantha Yang

APPENDIX C
COLLECTING AND ANALYZING INTERVIEW DATA

A. Reading Preparation

1) How would you rework these types questions to fit with your own interviewee and topic? In the context of this class, what are the limitations of this type of questioning, that is only in reference to an existing technology, and what types of questions can you ask that are not limited in this way?:

- When and why do you have such an experience?
- Walk us through your typical experience when you notice this concern.
- What is your current solution?
- Walk us through a typical experience using your current solutions.
- What do you like about the current solution?
- What do you dislike about the current solution?
- What factors do you consider when picking the solution?
- What improvements would you make?

Limitations: This flow will surround the discussion with the existing technology. The satisfaction and dissatisfaction are all limited by the starting point. There might be more suitable solutions that the customer has not thought of thus unlikely to be brought up in this conversation.

Proposed changes: Ask more questions surrounding their needs instead of just how they view certain solutions. Conduct research to explore the possible alternatives and ask for customer's opinions on them. Ask the customer to describe the ideal features the solution should have.

2) What is the purpose of capturing wording verbatim, rather than simply summarizing the responses throughout the interview? In what other ways is video recording and automatic transcript generation (e.g. the "Zoom" phenomenon) so valuable?:

Purpose:

- Writing down summaries on the spot could lead to misinterpretation of interviewees' response. There is no way to correct it later on if you only have the summaries to refer to.
- Document observations while the product is in use
- Bring new member up to speed
- Present procedure to upper management
- Can record and observe user from multiple angles

Additional value:

- Video recording can be used to capture information/detail missed in the interview.
- The investigators could review the recording to confirm an observation.
- Auto-transcription can help if the language is a barrier between need knower and interviewer. Real-time understanding is important to capture interesting responses from need knower and identify topics that can be expanded.

3) Summarize, on the whole, why is it important to follow the guidelines outlined on page 82-83 while first analyzing the data, and what is the primary outcome of such an exercise. Why is this not the final "Step" in the analysis process?:

Importance:

- To avoid implying a solution in the need statement which can limit solution brainstorming
- Avoid loss of information
- Avoids magnifying the need by using words like "should" or "must"
- Maintain consistency in the interviewee responses and facilitates the subsequent translation

Primary outcome:

- The primary outcome is a pool of needs translated from the customer's voice to unbiased requirements related to the solution. The needs can be used as objective raw data to guide requirement definition and engineering design.
- Why is it not the final step?
- The needs should be presented as objective statements before any further analysis and interpretation.
- In addition, the need statements are descriptive and generic which makes them suitable for further analysis. Hierarchical organization of need statements comes after this step to break down the general needs and distinguish important needs.

4) Describe how your team will adjust this exercise to perform it remotely, while still achieving the same step by step procedure suggested by the author.:

- Remote interviews will be easier to set-up because Zoom lets you record and even retrieve the transcript.
- It might however, restrict the amount of emotional or physical motions from the interviewee, but we can accommodate this by asking the interviewee to sit slightly away from the camera.
- The other steps can be easily adapted to online, there is not much difference.

B. Interview Preparation

1) To address before interview:

- Self-introduction: name, background, role in the interview
- Topic of this interview: your gaming experience and the occasional hand coldness you experience
- You can stop the interview at any time.
- You do not need to share anything that you don't want to
- We are here to learn about your experience and your current solution.
- Can we get permission to record the video and audio
- Will have live transcription recorded
- We will keep the recording on a password-protected device and delete it after completion of the analysis.
- Clarify we cannot promise to have a working prototype for him
- Any questions before starting?

2) Interview Questions:

- Icebreaker
  - What do you like about playing games?
  - Do you like cold weather or warm weather?
- Living condition: location (state), type of living situation, size, people
- General gaming experience
  - Could you tell us about your gaming experience?
    - How long have you been playing games?
    - What games do you play now?
    - How long have you been playing them?
    - How often do you play games?
    - How long do you play games for each time?
    - At what time during the day do you usually play?
    - Do you play alone or with friends?
    - When and why do you stop playing for each time? Is it ever due to discomfort?

    - How often and why would you pause the game?
  - Getting into scope
    - What fingers do you use for different gaming devices?
    - Most important fingers for your gaming?
    - What are the common hand movements for different devices?

- Gaming set-up: equipment, environment
  - What objects do your hands interact with during gaming? (mouse, keyboard, controller, etc.)
  - What other things do you usually need while gaming?
  - How much space do your gaming setup consume?
  - Where do you sit? What's your seat like?
  - Do you use AC or heaters? How close are they to you?
  - What are they wearing? In different seasons and before/after cold exposure

- Performance
  - How do you rate your skill level in gaming?
  - What factors do you think impact your performance? by how much?
  - Could you please describe such an experience?
    - What's the temperature outside?
    - What was the room temperature
    - What time during the day was that?
    - What did you do before starting the game?
    - What was the set-up for that time? As usual or subtle changes
    - When do you start to feel cold? Do you experience other physical discomfort due to coldness?
  - In which aspect does coldness affect your performance? Speed, accuracy?
  - What movement is affected the most? Precisive movements vs simple movements
  - Which hands are most affected? What part of the hand (wrist, fingers, fingertips? Which fingers?

- Discomfort/Needs
  - Do you start out with warm hands or cold hands before gaming?
  - What do you do when you are cold? How do you feel about this solution? Effectiveness and comfort (Gloves, portable heater, blanket for body, socks, etc.)
  - Hands getting cold in other activities?

3) Conclude the interview:

- Thank the participant.
- We will keep data confidential.
- We will try to identify a need and brainstorm some solutions
- Ask if it would be ok to reach out for a follow up if if needed
- Remind him that there is no obligation, and he can always say no without repercussions.

4) Role assignment:

- Lead Interviewer: Arsany Gad
- Secondary Interviewer: Samantha Yang
- Note-taker: Xiangjiu Wu

C. Interview Analysis

The one-hour interview covered all the topics as planned as well as additional followup questions as the need-knower described his experience. Figure 8 shows the needs interpreted from need-knower's statements in the interview. They are further categorised and ranked into hierarchical lists as shown in Figure 9.

Questions/Prompts	Customer Statement	Interpreted Need
General Operating Environment	I generally enjoy cold weather compare to a hot/warm environment.	The solution keeps the ambient temperature at comparable level as the original condition.
	I like to have a lot of space reserved for mouse movement. I even tilted my keepboard to free up some space.	The solution is placed out of the space reserved for mouse movement.
	My desk is pretty full. There is limited space that can be used on the table.	The solution takes minimal space of the table top.
	I sit about 1m away from the wall behind my chair.	The solution leaves enough space between desk and wall to allow the user move/walk through comfortably.
	Although I only use 1 of my 2 monitors for gaming, I don't move it away for gaming. I don't like changing my setup everyday.	The solution requires minimal adjustment after initial setup.
	-PC. 3 feet away from vent -Couch: 10 feet away from vent	The solution works even with ventilation from AC/heating.
	I still put on sweatshirt in summer when near the PC.	Solution is compatible with sweaters.
Typical Use Case	I play games almost everyday.	The solution operates on a daily basis.
	I usually play games for 2-3 hours continuously.	The solution operates up to 3 hours continuously.
	I almost always play with my friends and we have to communicate while playing.	The solution is quite while operating.
	On weekends, I would play games from 8:30pm to 1am. And earlier on weekdays, 5:30 to 8:00 pm.	The solution operates at night, independent of sunlight.
	I cannot stop in the middle of a game.	The solution operates without human interaction for at least 30 minutes continously.
	I only get up for water or other physical needs so I can always stay close to my PC.	The solution can be operated while the user is sitted.
	I like to move around on my swivel chair.	The solution maintains the smoothness and flatness of the flloor near the PC setup.
	I use thumb and index finger the most but generally all fingers needs mobility.	The solution allows free movement of all fingers.
	I use my wrist on right hand a lot to move the mouse.	The solution is effective for wrist.
Discomforts/Impact in cold	It's frustrating for him when his hands are cold. He sometimes complains to teammates about it.	The solution keeps his hands warm during gaming.
	Index finger is most noticeable affected because used a lot.	The solution does a great job at keeping his index finger warm because it's an important finger for gaming.
	Impact from coldness is very noticeable especially the speed. I cannot click mouse as fast.	The solution allows for quick clicking of mouse buttons.
	Right hand is impacted the most.	The solution designed mainly for right hand.
Likes - current solutions	Blanket cover the PS4 and hands. Do not usually need to see the controllers. Performance not impacted as dramatic (less repeated motion and less speed needed).	The solution allows him to keep up his normal performance without interference while keeping him and his hands warm.
	Blanket works pretty fast. But sweater is slower. 5-10 minutes or so. Personally don't care so much about how long it takes.	The solution warms him and his hands up in <= 5-10minutes.

Dislikes - existing solutions	If I were super rich, I'd buy a space heater for mouse space.	The solution is affordable.
	I am not a fan of handwarmers because you have to actively use it (stop gaming to start it).	The solution can be passively used while allowing gaming to continue uninterrupted.
	Small space heater probably uses a lot of power.	The solution uses minimal power.
	During PC gaming, he does not use blanket because he needs to see the keys.	The solution allows the user to keep a clear view of his keyboard and mouse.
	Gloves are bad for dexterity, it would be good to maintain dexterity for gaming.	The solution allows user to retain normal dexterity.
	I put on a sweater if cold. Blanket only works for ps4 but it is faster.	The solution can work for pc and ps4.
	Wearable solutions would be powerful.	The solution can be used during other activities. (!)
	If it could imrpove dexterity in a cold environment would be great.	The solution works for outdoor activities. (!)

Fig. 8. User needs interpreted from user's statements during the interview.

	The solution operates normally in the current environment
	The solution keeps the ambient temperature at comparable level as the original condition
	The solution is quiet while operating
*	The solution operates at night, independent of sunlight.
***	The solution allows the user to keep a clear view of his keyboard and mouse.
*	The solution can be operated while the user is sitted.
*	The solution takes minimal space of the table top.
	The solution leaves enough space between desk and wall to allow the user move/walk through comfortably.
	The solution works even with ventilation from AC/heating.
	The solution maintains the smoothness and flatness of the flloor near the PC setup.
	The solution works operates normally in a continous gaming period
**	The solution operates up to 3 hours continuously.
***	The solution operates without human interaction for at least 30 minutes continously.
***	Solution can work for both pc and ps4.
	The solution operates on a daily basis.
	The solution has other use cases
*	The solution works for outdoor activities.
	The solution maintains full dexterity of both hands
*	The solution allows for quick clicking of mouse buttons.
**	The solution can be passively used without interrupting game.
***	The solution allows user to retain normal dexterity.
*	The solution is placed out of the space reserved for mouse movement.
***	The solution allows free movement of all fingers and arms.
	The solution is a wearable.
	The solution requires minimal investment to set up
***	The solution is affordable.
	The solution uses minimal power.
	The solution keeps the user's both hands warm
**	The solution only warms up cooler hands and is breathable
	The solution warms him and his hands up in <= 5-10minutes.
***	The solution does a great job at keeping his index finger warm because it's an important finger for gaming.
	The solution is effective for wrist.
***	The solution keeps his hands warm during gaming.

Fig. 9. Hierarchical list of primary and secondary user needs. Importance ratings for the secondary needs are indicated by the number of *'s, with *** denoting the most valued needs.

D. Brainstorming Session Summary

The remote brainstorming session began with the team gathering all their ideas and categorizing them which revealed 6 overarching themes which include: wearables, software add-ons, finger warmers, modifications to gaming setup, gloves, and desktop appliances. Team members then voted on specific ideas they liked and ideas with the most votes were used later in a weighted matrix to decide on.

Fig. 10. Original ideas generated by all team members before categorization

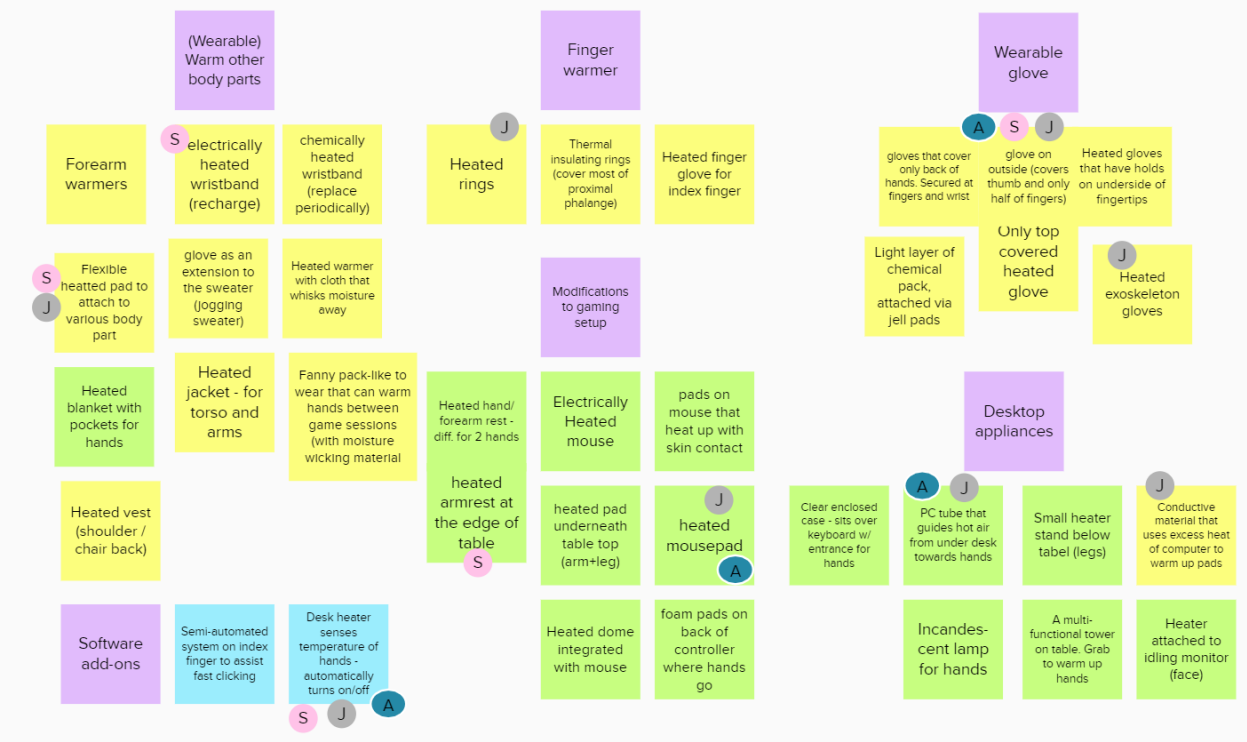

Fig. 11. Summary of brainstorming session with purple notes highlighting overarching themes of ideas generated. Votes of each team member as denoted as circles with the team member's first initial.

E. Final Matrix for Idea Selection

Based on each team member's preferences and perspectives, a final weighted matrix was created to solidify the concept that reflects the best option for the team moving forward.

Objective/Criteria	Weights	Sweater (their current solution)	Gloves that expose fingertips and palm: heated	Gloves that expose fingertips and palm: non-heated, two detachable pieces (velcro)	Heated mouse pad (with sensor to control temperature)	Desktop heater (with sensor and AI to control temperature): may add more features	Heated velcro pad to be attached to any body part	Redirect heat (hot air, conductive material) from PC to hand area
Effectiveness in heating up hands	0.25	0	0.500	0.292	0.167	0.333	0.250	0.292
Retains normal dexterity	0.22	0	-0.036	0.036	0.289	0.289	0.072	0.289
Retains limb movements	0.20	0	0.167	0.167	0.267	0.200	0.000	0.233
Cost	0.07	0	-0.111	0.000	-0.044	-0.133	-0.044	-0.111
Applicable to multiple use cases	0.11	0	-0.090	-0.018	-0.181	-0.108	0.000	-0.144
Achievability	0.09	0	-0.059	-0.015	-0.029	-0.147	0.000	-0.074
Team's interest	0.07	0	0.140	0.093	0.047	0.047	0.000	0.047
Total Score		0	0.510	**0.555**	0.514	0.480	0.278	0.531

Fig. 12. Final weighted matrix shows the idea with the highest weight as the non-heated dexterity gloves.

F. Selected Idea: Non-heated dexterity gloves

Product Description: The idea is to use non-heated gloves with exposed fingertips and palm areas to help maintain warm hand temperatures during gaming. The fingertips are only exposed on the underside to retain as much heat as possible and to retain fingertip haptics. The base of the palm is also exposed so that the part of the hand that normally sits on the table can still feel the mouse pad and helps gauge how far the hand is moving. The two exposed areas can be covered up during normal use with Velcro parts. The glove overall is slim in design as to preserve hand and finger dexterity.

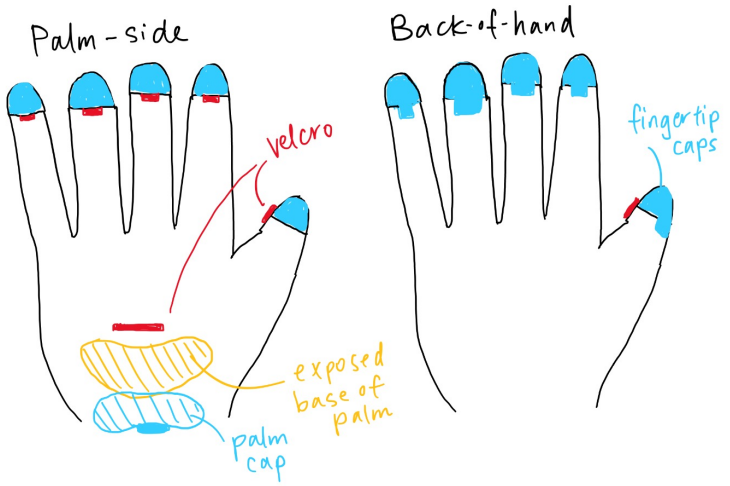

Fig. 13. Initial rough sketch: Non-heated dexterity gloves