CareMouse: An Interactive Mouse System that Supports Wrist Stretching Exercises in the Workplace

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ABSTRACT

Knowledge workers suffer from wrist pain due to their long-term mouse and keyboard use. In this study, we present CareMouse, an interactive mouse system that supports wrist stretching exercises in the workplace. When the stretch alarm is given, users hold CareMouse and do exercises, and the system collects the wrist movement data and determines whether they follow the accurate stretching motions based on a machine learning algorithm, enabling real-time guidance. We conducted a preliminary user study to understand the users' perception and user experience of the system. Our results showed the feasibility of CareMouse in guiding stretching exercises interactively. We provided design implications for the augmentation of existing tools when offering auxiliary functions.

CCS CONCEPTS

• **Human-centered computing → Interactive systems and tools**.

KEYWORDS

Interactive System, Healthcare, Intervention

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1 INTRODUCTION AND RELATED WORK

Musculoskeletal disorder is one of the most common symptoms among workers using computers often [7, 8, 21]. This problem is widely known as the term "Computer and Visual Display Terminals (CVDT) syndrome", meaning "An array of clinical symptoms related to prolonged and uninterrupted viewing of VDT (output terminal) or prolonged and repetitive use of its peripherals (input devices)." [17] Related to this, a large study with around 7,000 computer operators showed that using a mouse and keyboard for a long period of time negatively affects wrist health [12], and another study investigated the posture of using computers also affects the musculoskeletal symptoms [6]. The symptoms of musculoskeletal disorder vary, including pains in the neck, back, shoulder, upper limb, finger, and so on [2, 24]. In order to better understand how workers use their computers, prior studies also investigated the hand/wrist displacements when people type keyboards [1], the movements of fingers when they use a mouse [13], and how the mouse positions or operations affect the activity of multiple muscles including hands and arms [3, 9].

In particular for wrist health, researchers from the computer science field developed systems that monitor the user's hand or wrist behavior using sensors or provide interventions to prevent the users from musculoskeletal symptoms during their computer-based works. For instance, they used a force-sensing resistor and accelerometer to measure the fingertip forces and hand angles during the computer use for correction of hand movements [4] or a capacitive resistance flex sensor on a glove to monitor the angle b/w forearm and palm [15]. In addition, mobile applications were introduced that use the user's thumb inputs to classify or screen those who are already experiencing carpal tunnel syndrome in the early stage [5, 11]. In the case of designing intervention systems, they monitored the user's wrist angle and muscle activity using IMU and MyoWave muscle sensors and provided feedback through the LED screen and vibration. Moreover, they utilized multiple approaches such as virtual interface (Unity3D) with force feedback (Novint Falcon) [22] or LeapMotion controller and game-based graphical user interface [23] for designing a rehabilitation session (e.g., stretching exercises).

However, previous studies were lack of understanding the user; the design of the system was too complicated to use in the real world. For example, additional devices such as wearables, cameras, and VR were required to keep tracking the user's behavior and guide the stretching exercise. Even more, in some cases, sensors should be attached to the user's body for more precise monitoring, but it would be difficult to imagine that the users are willing to

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use these settings in their workplace. Also, few studies explored providing real-time feedback on the user's activities based on the user's exercise motions. Alarms and notifications could be useful in reminding users of the need for stretching exercises, but the users may not have prior knowledge about how to stretch thereby doing wrong motions or repetitions. Most systems that give simple instructions about stretch may not be appropriate for carefully guiding the users' exercise and tracking whether they really did something for their wrist health.

In this study, we proposed CareMouse, an interactive mouse system composed of a mouse and a mobile application that supports wrist stretching exercises. The system was designed to allow computer users to do wrist stretching exercises properly in their workplace by suggesting the exercise session and guiding the motions step-by-step. It provided several sample stretch motions and kept tracking the user's activity using a specially designed mouse; an IMU sensor and a machine learning algorithm were utilized to collect and classify the users' activity based on their own pre-trained motion data. Therefore, it enabled the users to confirm that they were on the right track by checking the correct movements and enough repetitions for each stretching motion.

To explore the feasibility of CareMouse, we conducted a user study with two research questions: (1) What is the user perception of this system, and (2) What are their user experiences when using this system? Results showed that participants perceived CareMouse as a natural tool for wrist exercise and an active and motivating coach for their health. They evaluated that the system was acceptable in terms of usability, and shared their user experience in terms of exercise components, monitoring and guiding the exercises, opportune moments for the intervention, and feedback after the exercise. Based on the result, we suggested several design implications for CareMouse, such as clear guidelines when utilizing an existing tool, less strict evaluation for the user's performance, and more engaging design by allowing customization.

2 SYSTEM DESIGN

2.1 Formative Study

Before we designed CareMouse, we first conducted a small-size focus group interview (FGI) to understand the needs of the stretch guide system. We recruited 4 participants (3 women, mean age: 30) who are graduate students of a large university, spending most of their daytime working with their computers. In this session, we asked questions such as how participants use their computer and mouse, how they manage their wrist health, and what they think about our system design idea. In the case of the third one, we briefly introduced our initial concept (i.e., a mouse that guides the user's stretching exercise) and had comments and feedback from the participants. We voice-recorded the FGI session with the participants' consent and analyzed the results to see which design components should be considered in CareMouse.

In the FGI, the participants reported that they use their computers for more than 8 hours per day on average. Especially, they interacted with their computers more (e.g., more mouse clicks and drags or keyboard typings) when making presentation materials, reading academic papers, surfing the internet, and playing games.

During their computer-based tasks, they have experienced wrist pains due to several reasons. For instance, they suffered from pain when they use the keyboard a lot for the paper submission or their wrist is too folded due to the height of the keyboard. In addition, they reported that they do lots of clicks and moves in their mouse use, which probably made the pain in their hand and wrist worse. However, they did not have their own strategy for preventing wrist pain. Most of them simply took some rest until it got okay, and when it became worse, they went to the hospital to get physical treatment. The participants guessed that the stretching exercises might be a good way of preventing the pain, but they usually did not try in their everyday life.

After introducing our initial concept, the participants suggested four main design considerations: "*The mouse should not be too big or heavy*", "*The stretching exercise should include familiar motions (e.g., rotate and tilt the wrist)*", "*The exercise should not be too long*", and "*Positive feedback should be given after the stretch.*" Participants mainly focused on how to make the user utilize this system for a long period and build a healthy habit. Therefore, they suggested strategies that lower the burden of doing exercises and motivate the user by acknowledging their efforts for their health.

2.2 CareMouse

We designed CareMouse based on the findings during the FGI session. CareMouse is a system that guides the user's stretching exercises by (1) capturing the wrist motions with an IMU sensor and (2) classifying the motion using J48 classifier [18], a decision tree classification algorithm.

The system was composed of two main parts; a sensor-implemented mouse and an Android mobile application. As shown in Figure 1, the mouse is composed of Bluno Nano (a small Arduino), an IMU sensor, and a 9V battery. We implemented these components to collect the sensor data (i.e., accelerometer and gyroscope) values when the user moves her wrist while holding the mouse and forward the values to the mobile application. Consequently, the size and weight of the mouse were $90 \times 40 \times 125$mm and 65g, similar specifications to the mouse widely used every day. In fact, our initial plan was to add the components in the existing mouse to allow the user to use the mouse as usual. However, due to the limited space inside the mouse, we had to remove all the internal parts and replace that space with the components.

The mobile application classified different wrist gestures and guided the user's exercise interactively. As shown in Figure 2, sensor data collected from the IMU sensor were kept forwarding to the application as long as the Bluetooth connection was made. Then the app parsed the data with a predefined sliding window, extracted

Figure 1: Components of CareMouse

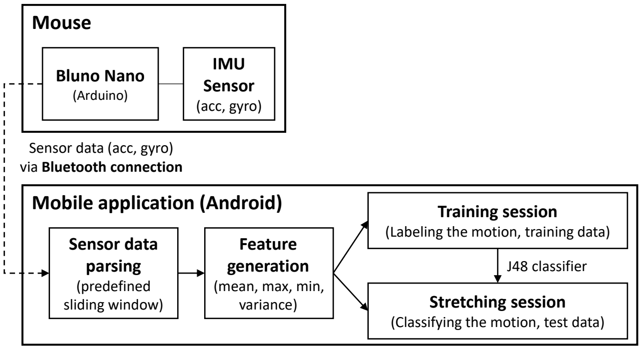

Figure 2: Overall structure and data flow of CareMouse

features (i.e., mean, max, min, and variance), and either labeled them into corresponding motion (i.e., training session) or classified them (i.e., stretching session). We decided the size of the window and step as 1 and 0.5s respectively after testing with several different combinations. The accuracy of the system was 82% on average when two authors iteratively conducted simple testing 20 times.

In the mobile application (see Figure 3), the user could first make a Bluetooth connection between the mouse and the application. At the very first time, the user moves to the "training" session and collects her own training data for each stretching motion. We prepared 5 different motions that are well-known and widely used for stretching exercises. They are composed of 2 static postures (extension and flexion) and 3 dynamic movements (vertical moves, clockwise rotation, and counter-clockwise rotation) as in Figure 4.

As the application shows the motion one by one, the user should keep doing it for at least 10 seconds while holding the mouse. During this process, the application automatically generates the feature values and labels them with the motion id. These features become criteria for evaluating whether the user's motion is accurate during the "stretching" session. Also, we allowed the user to update the training data when it is needed. Here, we assumed that the user will do the motion correctly during the training session and decided to use it as a standard. Since the sensor values may vary by the user even though we provided the same motion, we believe that setting the criteria based on the user's own motion is more plausible for the evaluation.

When the system suggests stretching exercises and the user follows it by running the stretching session. In this session, the user's motion is classified into a certain label every second based on the training data. The application shows a progress bar for the stretching session and updates it only if the label matches the current motion's id. Also, we set the minimum number of repetitions as 10 times, meaning that the application shows the next motion automatically if the label of the user's current motion exceeds this threshold. We decided on 10 repetitions to let the user finish each motion within 10 seconds and make it not too long. As the stretching session is finished, the application shows a smiling face with the message "Well Done!" to acknowledge the user's effort. After this session, the user can go back to the main page and repeat the exercise when the next alarm comes or whenever she wants.

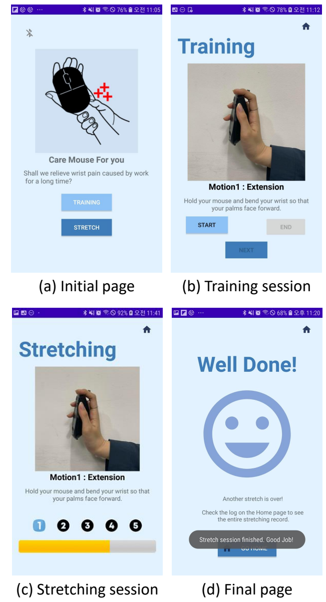

Figure 3: Screenshots of CareMouse mobile application

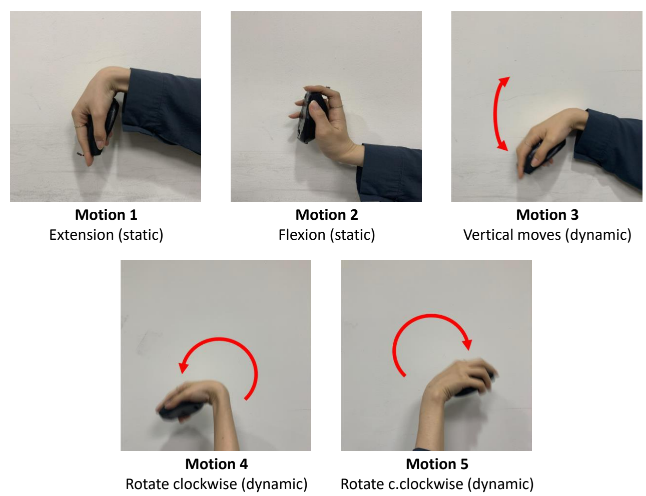

Figure 4: Stretching exercise motions in CareMouse

3 USER STUDY

3.1 Procedure

We conducted a user study with 6 participants (4 women, age (mean): 28.8) to understand the user experience of CareMouse. Participants had different occupations (1 researcher, 4 graduate students, and 1 other), but all of them reported that they work with a computer for more than 6 hours per day.

In the study, we introduced how CareMouse works and let the participants collect their own wrist motions using the training session. For each motion, they kept the same posture or movement for at least 10 seconds for extracting the features and labeling them.

After labeling the features with corresponding motions, we allowed them to try one stretching session to double-check whether they understand the system.

Since we targeted the system to be used in the workplace, we prepared hypothetical tasks (25 mins) to make the environment similar to the participants' everyday life. We gave two tasks during the study: (1) summarizing a paper (10 mins) and (2) making a presentation slide (15 mins). While doing these tasks, the stretch alarms were given every 7 minutes so that the participants did stretching sessions with CareMouse. We set this interval to allow the participants to interact with the system at least three times. Note that as we removed all the internal components due to the limited space, we prepared an additional mouse with the same model so that participants can do the tasks using the original mouse and switch to CareMouse when they stretch their wrists. By doing so, we tried to make the participants experience the system as if they were using one mouse.

After the study, we provided a survey questionnaire based on the System Usability Scale (SUS) to evaluate the usability and conducted a semi-structured interview to understand the overall user experience, their interactions with CareMouse, and comments for further improving the system. The interview was recorded with the consent of the participants, and we conducted a thematic analysis after the user study.

3.2 Results

3.2.1 Perception of CareMouse. Most of the participants perceived CareMouse as a natural tool for stretching exercises in a less intrusive way. As P5 mentioned, "*It was good to naturally lead to stretch during the task.*" P6 said, "*It was not difficult to switch from the task to stretching exercise since I kept holding my mouse. I didn't have to change the motion that much for the exercise.*" They also noted that it utilized a familiar tool, as P3 mentioned "*It was novel and interesting to utilize my working tool in guiding the stretch.*" However, some of the participants reported inconvenience partly due to the way they held the mouse (P1, P3) and the size or weight of the mouse (P5). Nevertheless, "*these inconveniences were limited and acceptable*" (P2, P6), and they "*felt a similar refreshing effect after the stretch as they experienced in the normal stretching exercises.*" (P4)

CareMouse acted as an active coach that made the participants care more about their health. It affected the participants' perception of the need for exercise. P6 and P5 mentioned, "*it made me think about what would happen if I don't stretch regularly*" and "*it was great as I could exercise consciously because I usually did not recognize that I was putting my wrist on the desk for a long time.*" Moreover, the participants responded that "*the alarm was effective in actually starting the stretching sessions.*" (P1, P2) Interestingly, the system acted as a trigger for other exercises as well. As P4 mentioned, she "*wanted to do the same stretch with her left hand and stand up from her seat.*" In addition, P6 said "*CareMouse was a good starting point for the exercise. Maybe I will look for the related video clips and do more exercises because of this.*"

3.2.2 Usability and actual use of CareMouse. From the SUS survey, the participants rated 70.4 on average (SD: 16.5), which could be considered as an acceptable system. 4 out of 6 participants rated more than 70 points, but 1 participant (P5) gave 40 points mainly due to her repeated failures in motion recognition when using the system. More specifically, the participants showed the most positive response for the complexity of the system (mean: 3.7, SD: 0.8) while negative evaluations for the need for support to use the system (mean: 2.0, SD: 1.3) and learn a lot of things before using it (mean: 2.0, SD: 1.3).

	Motion 1	Motion 2	Motion 3	Motion 4	Motion 5	Overall
P1	7.3	6.7	7.7	7.3	6.3	35.4
P2	7.6	18.5	8.0	6.0	6.2	46.2
P3	26.2	8.8	6.7	6.1	6.1	53.9
P4	25.3	7.5	10.9	6.6	5.7	56.1
P5	12.6	13.4	8.0	11.2	33.8	79.0
P6	12.3	13.7	9.1	6.8	6.2	48.1
Mean	15.2	11.4	8.4	7.3	10.7	53.1

Table 1: Time spent for each motion (in second)

As illustrated in Table 1, the participants spent 53.1s on average (SD: 16.59) to finalize one stretching session. There was a difference in the time taken to finish each motion, ranging from 7.3s to 15.2s on average. In general, the participants experienced more difficulties in motion recognition during the static motions (i.e., motion 1, 2) compared to the dynamic ones (i.e., motion 3, 4, 5), thereby tending to take more time in finalizing it. In the case of motion 5, P5 spent a longer time than others due to her wrong motion in the training session. Except for that result, the dynamic motions were shown to be recognized better.

3.2.3 User experience of CareMouse. First, the participants thought that the length and components of the stretching session were appropriate. They mentioned that the length of the session was not too long to do during the tasks (P1, P2, P4). P6 said it depends on the frequency of the exercise, saying "*I could do longer stretching sessions than this study if the term between the sessions becomes longer, for example, 1 hour.*" Also, they said that the motions were not difficult to follow (P1, P2) and they felt it was more effective when they did the dynamic motions (P3, P4). For the number of motions, P3 answered "*Around 3 motions with enough movements will do*" whereas P6 did "*More motions are needed for the effect of exercise.*"

At the beginning of designing CareMouse, we mainly focused on checking whether the user followed the stretching motion accurately. However, it turned out the criteria were too strict to recognize the participants' stretching motions well. P5, who suffered this issue the most, said "*It was annoying that the progress bar was not updated even if I followed the given motion. Especially, the counter-clockwise rotation was not detected well.*" P1 also showed a similar opinion, saying "*I had to focus more on how to grip the mouse because the recognition criteria were quite sensitive.*"

As described in the previous subsection, the detection accuracy was varied by the motion type (i.e., static vs. dynamic). P3 mentioned "*the dynamic motions were better detected*", and this corresponded with the results about the stretch time. P6 wondered the reason, saying "*I was not sure, but the static stretching motions were not well captured maybe because I was not used to them.*" When the motion was not detected well, they "*tried to change the angle*" (P3) or "*adjusted their motion until the progress bar was changed*" (P6).

From their experiences, participants suggested more interactive guidelines and feedback for each motion. P3 said, "*The motion* *detection was also affected by the position of my elbow, so I think a more detailed explanation should be given to the user.*" P6 provided an idea; "*It would be better if the system shows the picture of sample motion and my wrist's current motion (via camera) at the same time. Then I can easily change my motion referring to how much they are overlapped.*" Other participants suggested applying less strict criteria in motion detection, saying "*the system should allow some errors*" (P4) or "*it should give an option to move on to the next step when the progress is above a certain threshold, not simply waiting until the motion is correctly done*" (P5).

In the study, the participants noted that the period between two consecutive alarms was very short even though they consider this is an initial evaluation, and it is critical to find an optimal intervention frequency in designing CareMouse. They said "*It would be bothersome if I should do stretching exercises this frequently.*" (P3, P4) and "*It could hurt my wrist if I follow all these frequent exercises.*" (P2) In addition, P1 mentioned the context of receiving the alarm, saying "*It was okay in the user study, but in the real world, the alarm should be designed with consideration of the user's context.*"

In the interview, they suggested several ways to find the opportune moments for sending stretch alarms. For instance, the system could allow the user to set when to receive the alarm. (P2) In addition, the system can utilize the user's context such as measuring the fatigue level using the number of clicks and typings (P1), detecting and intervening when the user is taking a rest or doing non-work activities (e.g., watching YouTube) (P3), or training opportune moments based on the user's prior responses. (P4)

The participants responded that the smiling face at the end of the stretching session was encouraging (P4, P6). However, they thought more active and interactive feedback would help motivate the user to keep using CareMouse. For instance, P1 described, "*There should be more clear cues that make the users feel they did well enough. For instance, the system can give a badge as a reward or show a message such as 'your wrist can live longer.'*"

4 DISCUSSION

In this study, we designed an interactive guidance system for office workers to do stretching exercises using a mouse. We tried to provide real-time feedback based on each user's pre-trained motions and allowed them to stretch the wrist accurately. From the user study, we could explore the feasibility of utilizing the mouse as a supporting tool for a simple exercise. This study could be seen as a renovation of a familiar tool that considers the users' context and enables their health management in a more natural and interactive way. Based on the findings from the study, we provide several design implications.

4.1 Design Implications

4.1.1 Clear guidelines when utilizing an existing tool. In the study, the participants reported that they had never experienced stretching exercises while holding a mouse, and this made their stretching partly uncomfortable. In fact, it did not matter how to hold the mouse since the IMU sensor could collect the movement data regardless of the grip. However, the prior experience of using the mouse made the participants put their index and middle finger on the mouse button and hold the side of it with other fingers. After the interview, some participants tried different grips and found the movement became way easier. Therefore, when we utilize a familiar tool and extend its function, we should provide explicit guidelines to be free from existing affordance [16]. In our case, the system can state that the grip does not matter or show sample motions with different grips.

4.1.2 Less strict evaluation for the user's performance. We tried to guide the user to follow the motion correctly, but the exact matching with the trained motion may not be a good approach for the actual use. In the study, the participants cannot perfectly remember and repeat what they have done in the training session. However, the criteria required them to achieve higher accuracy than they expected and made the exercise difficult. For improving the system, we may consider applying less strict evaluation or allowing some error as it is in the statistical process control [14]. In the manufacturing field, workers set upper and lower control limits and assess the output as "good enough" as long as the quality is within that range. Prior research also found that this concept could provide positive effects in increasing the motivation for more attempts [10], so we may apply the same concept for a better user experience.

4.1.3 More engaging design by allowing customization. From the user study, we found that the participants enjoyed the stretching session easily with less switching cost (from work to exercise) and were motivated by the system's interactive manner. However, we should also consider more about how to make this system more engaging for long-term use in terms of health management, as participants commented.

CareMouse could be seen as a tool for behavioral change; making the users do exercise regularly and think more about their health. In this sense, customization of stretching exercises could be a "goal-setting" process. Prior studies have explored various types of goals based on who sets the goal; for instance, it could be self-set, assigned, participatory, guided, and group-set [20]. Therefore, we may allow users to set up their own goals (i.e., stretching motions to do) and see how it affects their engagement with the exercise. As it is a health-related activity, however, it is critical to provide guidelines in advance to avoid them from exercising exercise incorrectly. For instance, the system could first give sample motions, and the users select among them. In that case, we should carefully design the interaction between the user and the system during the collaborative goal-setting process.

4.2 Limitations and Future works

In this study, we could not merge the existing mouse and the sensor module due to the limited space inside the mouse. As we explored the feasibility of doing stretching while holding a mouse, we can merge the two and conduct further studies. We expect that the complete CareMouse could monitor the user's mouse usage behavior in everyday life and detect the opportune moments for suggesting the exercises. To assess the effectiveness of the system, we should deploy CareMouse in the real world and conduct a long-term study in the future. We may measure muscle fatigue using Electromyography (EMG) sensors [19] to see the effect of CareMouse (i.e., comparison between with/without CareMouse). Also, in terms of renovating the existing tools, we may consider other devices for monitoring and coaching the user's exercising activities in future works.

5 CONCLUSION

We proposed CareMouse, a mouse system that guides the user's stretching exercise in real-time by utilizing a sensor. From the user study, we explored the feasibility of the system and found its potential usefulness for those who use computers in the workplace. We expect that CareMouse could be improved based on the several design implications we have discussed, and we believe that it could be a meaningful approach for managing the user's health by renovating the familiar tool within the user's context.

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