2011 TUI FINAL – Back/Posture Device

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INFO262, Jan-May 2011, Berkeley, California, USA. Copyright 2011 ACM...$5.00.

Abstract

In this paper we present a new type of tangible user interface designed to aid people with back injuries. The interface uses tactile and visual feedback to condition a user to maintain proper posture. The system includes a modular device that is worn by the user. The device uses LED lights and vibrations to guide a user when their back is bent to varying degrees, and when they are bending sideways from the waist. Users with back injuries may start physical therapy with a physical restraint device first before advancing to this new interface.

Keywords

Back injury, posture, accelerometer, haptic feedback, visual feedback, physical therapy, tangible interfaces, physical interaction

ACM Classification Keywords

J.3 Life and Medical Sciences: Health. B.1.1 Control Design Styles: Hardwired control. H.5.2 User Interfaces

General Terms

Guidance, feedback, posture, back injury, LEDs, vibrations

Introduction and Inspiration

Our work in the design and development of a tangible user interface builds off of prior work performed for a mechanical engineering project at the University of California, Berkeley. In that project, a mechanical device was designed and fabricated for people with back injuries. The device includes a static metal arm attached to a harness on each leg. This mechanical device allows the user to move freely while they are standing vertically or walking. When the user bends their back forward the device provides resistance to help prevent further back injury.

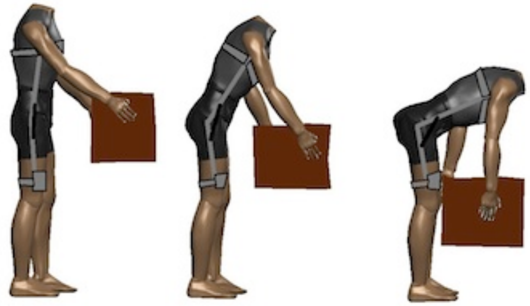

Figure 1: Our inspiration is a metal device designed to prevent improper motion by using an arm with resistance.

We studied this mechanical motion-restricting device to understand what role it plays in the physical therapy process. We observed the physical elements of the device. These include a support harness on each leg, a support harness worn on the chest and wrapping around the back, and an aluminum device on each leg. We studied the role of the device. The user can move freely in some positions, including walking and standing still. The user is restricted from moving in other positions, including bending their back forward. The device engages as the user bends forward, restricting motion.

We also gained an understanding of the intended user of the device. In our estimates the wearer of the device would be expected to wear three harnesses supporting two mechanical devices. The human side of this suggests an immediate response to the cold nature of metal and straps. Further discomfort could be expected from the weight of the device.

The sad reality is that the mechanical device is not intended to be a fashion statement, rather it is a medical device designed to aid in recovery from back injuries, or prevent back injury in the case of a user who may perform a job that requires lower back muscles. An example is a gardener who is bent over all day. Another example is the support staff at hardware store that is lifting heavy products all day.

Our Tangible Interface

With the mechanical device as our starting point we attempted to address back injuries from another perspective. We wanted to remove the physical restraints that prevent motion. We also wanted to support the user as they progressed beyond immediate injury toward their normal life again, this might include physical therapy after a user has healed from any injuries they may have. Instead of addressing lower back injuries with resistance we decided to encourage proper body position.

The result of our work is a lightweight box with minimalist design. Our prototype is fabricated with aluminum and attaches by velcro to a lightweight strap around the chest. The device offers visual and haptic feedback to the user. Three LED lights that are embedded into the box provide visual feedback. Two tiny spinning motors that are attached by Velcro to the left and right side of the chest strap provide haptic (vibration) feedback.

Train the First Time User

We created a training exercise for first time users. They learn proper body positions for good posture. The user is guided by the visual and haptic feedback from the device. Our first goal in the training exercise is to identify the user's baseline body position. They are asked to stand up straight and hold the position. Our device records the position. While this is happening the device displays a progression of LED light feedback. First one red LED lights up, then two, then three. When the device is ready it displays light from a green LED.

After the device has captured the user's baseline position we encourage the user to learn about the devices feedback. We do this by first asking the user to bend sideways from the waist slightly to the right side. As the user leans sideways the LED display on the device changes color from green to red. The motor on the right side also begins to vibrate, giving the user an indication that they are in a sideways body position. We repeat this process by asking the user to bend sideways to the left side. Similar feedback is provided from the red LEDs and the motor on the left side.

The next step is to teach the user how the device responds to forward bending motions. We begin by asking the user to stand straight up. This is the baseline position we started with. It is already configured and we don't need to do it again. The user is then asked to bend their back slightly forward from the waist. The visual feedback changes from one green LED to one red LED. The user may continue to bend further forward, or they may stand up straight again. The next step is to bend slightly further forward. The user is provided additional feedback in this situation. There are now two red LEDs displayed and both of the motors being to vibrate in a pulsing manner. The user is advised to stand up straight again. We use this as opportunity to describe how the device provides visual and vibratory feedback as the user bends further forward. The display returns to a green LED as the user stands up straight again.

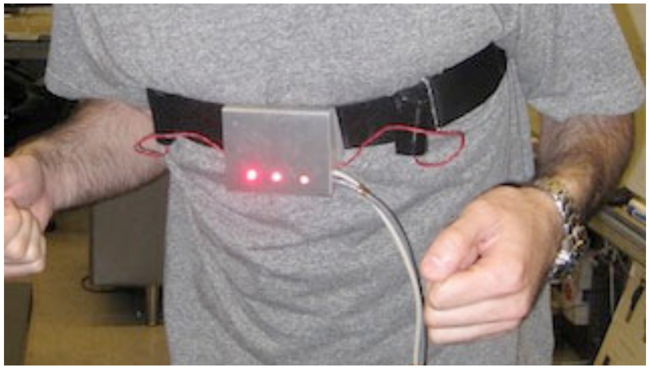

Figure 2: The posture device prototype attaches by Velcro to a minimal chest strap. Haptic vibration motors attach to the same strap.

The next step of the training is to ask the user to bend forward again, this time further forward than the last time. The device responds with three red LED lights and both motors vibrate continuously. This feedback continues until the user's back is no longer bent forward. The user is then asked to stand up straight again.

Our training continues to teach the user by asking them to perform two physical actions. The first action is without resistance, whereas the second involves resistance. In the first action the user is asked to stick their arms out straight in front them. Then they are asked to squat by bending their knees while their arms are still straight out. As they squat the device on their chest provides feedback regarding their back position. The user is then asked to stand up straight again. We offer verbal feedback to the user to explain how they are supposed to bend from the knees while keeping their back straight. The device indicates when they are bending their back forward.

The second physical action involves lifting an empty small box from the floor. The user is asked to stand up straight to begin the action. Then they are asked to squat with good back position. They pick up the box with their hands and stand back up again. The user is provided visual and haptic feedback from our device throughout the process. Squatting again to place the box back on the floor completes the action.

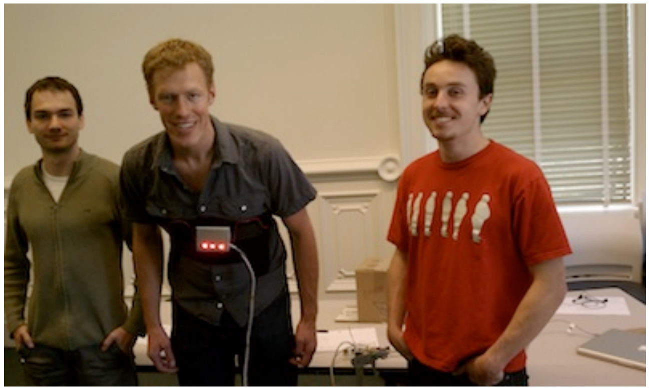

Figure 3: (l to r) Alex, Walter and Erich. Walter is demonstrating the posture device with his back bent at the waist. The totem is on the table in a similar position.

Evaluation

After using our device on a few test subjects we have learned a few things. The device is currently designed to identify a baseline position for each user. This works really well. We are currently capturing the motion of bending forward. This is calibrated for a level of sensitivity suitable for demonstration purposes. If this device were to be used in a real physical therapy session it could be tailored for each individual user. A good body position for one user may be a little different for another user. The angle of incidence that triggers the visual and haptic feedback can be adjusted within our code. The important part is that a user may need to be measured by an expert to identify what is appropriate for their level of injury or recovery.

We allowed users of our prototype to try it out. They gave us positive feedback. Initial evaluations suggest that we will want to accommodate for a variety of body sizes and shapes. Back position can be measured with the current device, but the chest strap we attach it to should fit a little better. Other feedback suggests that the visual feedback on the device is visible to the user but more appropriate for an observer, for which it works great. The observer is able to immediately see when the user is in a position with one, two or three red lights. The haptic feedback has the opposite quality. The observer is unable to feel the vibrations, whereas the user is able to feel it easily. Test users first reaction to the thought of the vibrations was skeptical. They were concerned it might hurt. Fortunately there was nothing to worry about. The vibration was mild and comfortable.

If we were to evaluate our back and posture device for real users we would want to explore ranges of motion of real back injury patients. We would also want to do a longitudinal study of patients as they progress through their recovery process. This could guide us with regard to the calibration settings. It would be nice to know if there were ranges of back angles that people of a certain type (size, weight, shape, gender) comfortably fit into. We also would benefit from an understanding of when a user should and should not bend greater than any given angle.

A future version of the device might include settings to change calibration settings from the device rather than from within the computer code directly.

The Totem

In addition to the tangible interface worn by the user we also created a totem. The totem is made of aluminum and is shaped to look like a person's outline. This totem has a free-hanging arm and it bends at the waist. When the user bends at the waist the totem mimics the motion.

In our current implementation we use the totem as a communication tool for someone who may have a vested interest in the well being of the user wearing the back/posture device. We imagine a physical therapist might be able to sit in another room while their patient is in physical therapy. When their patient bends too far too many times they could see it. And if they want to communicate back to their patient they can press a button on the totem. This button is currently connected to the vibration motors. This feedback could be used to tell the patient that they are being watched, and that they are moving incorrectly.

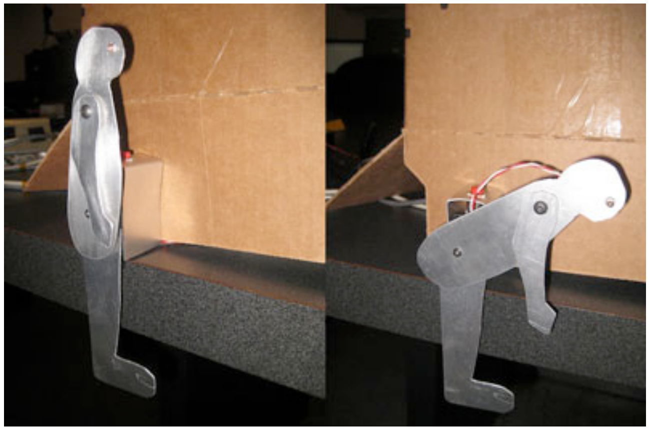

Figure 4: The totem attaches to flat surface. It bends at the waist and moves at the same time and in synch with the user wearing our device. The button is connected to the vibration motors on the user's device.

Physical Components

Inputs: Accelerometer (1), Button.
Outputs: LEDs (4), Vibrating motors (2), Servo
Materials: Breadboards (2), aluminum

Prior Work

In researching for this project we were interested in what currently exists in the medical device space for lower back injuries. We also were interested in what was available for visual and haptic feedback in the medical device space. We discovered the mechanical device being made in the Mechanical Engineering department at UC Berkeley. We also learned about feedback devices for blind people. These devices used vibration to guide a person toward a destination.

Support for our feedback device in academic research

1. Use multiple modalities (visual and tactile) to enhance task effectiveness.

Excerpt from Source:

Based upon Wicken’s Multiple Resource Theory (MRT), information delivered using multiple modalities (i.e., visual and tactile) could be more effective than communicating the same information through a single modality. The purpose of this meta-analysis is to compare user effectiveness when using visual-tactile task feedback (a multimodality) to using only visual task feedback (a single modality). Results indicate that using visual-tactile feedback enhances task effectiveness more so than visual feedback (g = .38). [1]

2. The “impact-perceive-adapt” model of user performance explains the need to adapt our system for time delays between actions and response by visual vs. haptic response.

Excerpt from Source:

Our results demonstrate that haptic feedback in particular is very sensitive to low levels of delay. Whilst latency affects visual feedback from 50 ms, it impacts on haptic task performance 25 ms earlier, and causes the haptic measures of performance deterioration to rise far more steeply than visual. The “impact-perceive-adapt” model of user performance, which considers the interaction between performance measures, perception of latency, and the breakdown of perception of immediate causality, is proposed as an explanation for the observed pattern of performance. [2]

3. Visual feedback can cause users to get caught in an attention demanding loop. Only use it for training purposes. After training allow the user to turn it off and rely on haptic response.

Excerpt from Source:

The conducted experiment uses a novel apparatus called "Hot Wire" that allows retaining the properties of wearable computing even in laboratory environments. Visual feedback was found to impair user performance and caused users to be caught in an attention demanding closed feedback loop once presented in a head-mounted display. Even though continuous feedback was not necessary for gesture interaction, users were unable to ignore it and remain focused on the primary task. The design of an alternative gesture recognition method using a body-centric frame of reference instead of a conventional static one to improve usability, is shown to have an opposed impact both on the performance and subjective perception of users. [3]

4. Justification for using visual and auditory feedback (it’s the norm) and haptic feedback as alternate means to communicate.

Excerpt from Source:

For a human communicating with a computer the predominant means are still as follows: Human-to-computer communication (computer input) uses keyboard, voice and pointing devices; in all cases including ones not mentioned, there is usually a feedback, mainly visual and supported by sounds. For computer-to-human communication (computer output) there is a very large variety of visual and acoustic modes available. The distribution of modes between human and computer is quite unbalanced. Some important channels available to humans, like those corresponding to the senses of touch, smell or taste, are only used rarely if at all in human-computer-communication; the heavy reliance on just vision and hearing incurs an inevitable loss of information. This situation is acerbated when the human’s ability to use vision or hearing is impaired or absent.

For a blind computer user the visual feedback as well as the visual output have to be substituted, and this is mainly achieved by haptic and acoustic devices together with some kind of keyboard and voice used for input. [4]

5. Calibrated vibrations on the chest could be used to provide feedback to the user.

Excerpt from Source:

Vibrotactile Communication: A vibratory communication system (called Vibratese) was developed in the fifties [Geldard, 1957], where five calibrated vibrators placed on the chest, each varied in three intensity levels (20 to 400 μm) and three durations (0.1, 0.3 and 0.5 sec) at a fixed frequency of vibration of 60 Hz represented a 45 element system consisting of the single letters and digits. Subjects could learn the code in about 12 hours and be able to receive 38 words per minute (a word being five-letters) [Tan, 1996]. [5]

Acknowledgements

We thank the UC Berkeley School of Information for the Tangible User Interface course offering. We thank Kimiko Ryokai, Daniela Rosner and Niranjan Krishnamurthi for their assistance throughout the course. We thank the UC Berkeley Mechanical Engineering department for their fabrication equipment and materials.

Citations

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