Supporting Shoulder Pain Prevention and Treatment with Wearable Technology

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ABSTRACT

This research examines how wearable technology and supporting applications can help office workers maintain good posture and guide them to carry out shoulder exercises at their workplace. Specifically, we describe a smart garment designed to monitor upper body posture that provides vibrotactile notifications at different joint areas in order to remind users to correct their posture. We present the design and evaluation of a related smartphone application that supports shoulder training exercises to treat and prevent shoulder pain. The usability of the system for shoulder training was evaluated positively in a laboratory test (N=17). The effectiveness of the system for posture monitoring was assessed with a field deployment (N=25) in which students working with laptops used the posture monitoring system for a whole day. The results demonstrate the system can help the participants facilitate improving their posture in sedentary work.

Author Keywords

Wearable technology; shoulder pain; behavior change; instant feedback; summary feedback; posture correction

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Shoulder pain is very common influencing adversely arm function and the psychological state of people, decreasing daily life performance and increasing anxiety or depression [1]. A review of 17 studies on prevalence of shoulder pain found that results range between 6.9–26% for the point prevalence, 18.6–31% for the 1-month prevalence, 4.7–46.7% for 1-year prevalence and 6.7–66.7% for lifelong prevalence [4].

The occurrence of shoulder pain can be related to improper sitting posture and limited exercise for the shoulder joint; it may already afflict people during early adulthood [5]. Poor posture is often associated with computer work as users often maintain poor postures for a long time while focusing on their screens. Researchers have suggested that educating users on how to sit correctly while working with computers can help reduce shoulder pain [2]. However, maintaining a good posture is not simply a matter of knowing how to sit correctly, but of remembering to do so, and being able to comply to related advice consistently.

Advances in wearable sensing open up the possibility to apply technologies for the prevention of musculoskeletal disorders [6]. Wearable technology has been widely used for posture and movement monitoring [7]. Comfort, aesthetics and other practical requirements also need to be addressed along with accuracy and unobtrusiveness in order to enable regular use in different contexts where people live and work. Further, the manner in which postural feedback and advice are presented to users is crucial for the

Figure 1. Office worker wearing the posture monitoring garment and using the shoulder training application

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effectiveness and acceptance of such technologies. Currently most available solutions are limited to simple audio or vibrotactile notifications for poor posture. These help remind users to correct their posture but can also be annoying or completely ignored if they arrive at an inconvenient moment.

This research explores how wearable technology and multi-model feedback supporting posture correction and shoulder training exercises in daily computer work (see Figure 1). While shoulder pain prevention is interesting for various age groups, this study targets young adults who spend substantial time with computer siting at their desks. The ZISHI smart garment for posture monitoring [8] has been enhanced to provide vibrotactile notifications at different joint areas in order to suggest adaptations to posture. A supporting application named ZUOZI has been designed which supports two modes of operation, a "shoulder trainer" mode and "continuous shoulder tracker" mode.

RELATED WORK

There have been quite a few studies that developed wearable posture monitoring technology. Previous work such as monitoring the posture of the lower back [15,16] or the trunk [21] have demonstrated the potential wearable systems for tracking posture. Compared to technologies such as optical motion recognition or robot-based tracking, wearable systems can bring advantages pertaining to lower costs, fewer restrictions/constraints upon the operational environment and low intrusiveness, which may even allow their use during daily life. A good example of a low cost consumer level wearable device is the Lumo lift [11] a device providing vibrotactile feedback for posture correction, reminding its user to back up. However, the movement of the shoulder involves several joints that connect to various tendons and muscles and simply keeping the torso straight up does not constitute a correct posture. Rather the shoulder girdle should be stable with arm movements below 60 degrees which is so for most sedentary occupations [23]. Thus to discriminate different postures reliably several sensors needed to be attached at different parts of the body. Wang et al [21] use accelerometers to support thoracic posture tracking. They emphasize how attention must be paid to placing sensors accurately and fitting them close to the body to prevent measurement artifacts resulting from deformations or movements of the garment.

Such posture monitoring technologies need to be coupled with effective feedback mechanisms that will help and motivate users to correct their posture. Common to the technologies described above is the emphasis on providing real time extrinsic feedback regarding the posture, what is often called knowledge of performance [17]. During the initial stages of a posture correction scheme this may help users understand how to improve posture, though it could lead to reliance on this feedback [15]. In order to track progress and motivate behavior change, also knowledge of results is required which describes the performance of the subject with respect to a set goal [17]. Typically, a combination of both forms of feedback in order to support motor learning is necessary.

A recent survey of empirical evaluations of posture feedback technologies used in rehabilitation advises against relying exclusively on the visual modality [15]. This is even more so for posture monitoring through the day when the user's visual attention is dedicated to different tasks. Accordingly researchers have explored the use of haptic feedback intended as a peripheral display [18] and vibrotactile feedback [11,14,22]. However the integration of such feedback with wearable technology capable of monitoring shoulder movements has not been reported yet.

A SHOULDER POSTURE TRACKING AND TRAINING SYSTEM

We introduce a shoulder posture tracking and exercise training system which comprises of a smart garment called ZISHI [20] and an android application called ZUOZI. ZISHI [20] integrates smart textiles and wearable electronics for detecting postures (Figure 2). One 9-dof inertial measurement unit (IMU) is fixed on each side of shoulder and two more are fixed over the T1 and T5 vertebrae of the thoracic spine. The sensor readings are used to calculate the angle of the torso and shoulder of the user. The position of the sensors on the shoulders is adjustable using a strap that can be fixed with Velcro on different positions of the shoulder. Sensor data is sent to a smart phone via a Bluetooth module embedded on the garment. The garment can also deliver haptic feedback (see Figure 3) on the body of the user. All electronics are integrated in plain vest which is designed as a normal garment to be worn through the day, allowing users to track their posture without disturbing their work.

The ZUOZI application contains two functions: a shoulder trainer and continuous shoulder tracker. These are described briefly below.

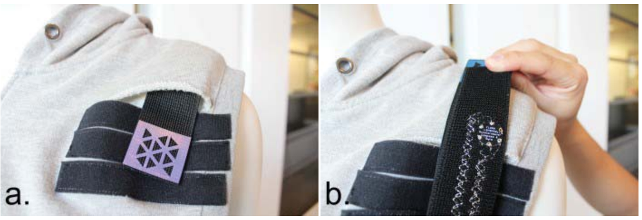

Figure 2. Sensors on ZISHI. (a)Front view of the elastic strap (b) IMU sensor embedded on the strap by conductive yarn.

Figure 3. Vibration module on the vest.

Keep on!

Sit straight!

Your correct time in this exercise

Your correct time in this exercise

Abduct your arm less with
palms forward within 40 degrees

Repeat this movement in 10 times

Try to touch your left shoulder with
right hand and then change to another side

Repeat this movement in 10 times

Figure 4. Screenshots of continuous shoulder tracker (top) and shoulder trainer (bottom).

Continuous Shoulder Tracker

The continuous shoulder tracker contains two different kinds of feedback: The first is the instant feedback on current posture. If the user is in a correct posture the ring will be in green with the words “Keep on!” If the user is in a wrong posture the ring will become red with the words telling “Sit straight!” (see Figure 4). If the poor posture lasts for longer than 10 seconds, the application will send a signal for vibration to the vest with Bluetooth. The second is the performance of user in the hour scale and day scale. Knowledge of results is supported with the summary feedback provided here.

Shoulder trainer

The self-exercise tutorial instructs users how to perform shoulder training exercises independently. Research already indicates that in persons with musculoskeletal shoulder pain, a scapulothoracic posture retraining program results in reduced shoulder disability and pain[1]. Following the suggestion with the therapists, we included 6 kinds of exercises that required stable scapula, e.g. arm abduction with 40 degrees (see Figure 4). The black circle in the middle of the bar is the current value of the ‘shoulder angle’. The green part means correct range. The red part means wrong range. Different shoulder exercises have different correct and error range. If the user does a certain shoulder exercise correctly the black circle is expected to fall into the correct range. If the movement is incorrect the black circle will fall into the error range and the system will count an error. The number displayed underneath indicates how many times a shoulder exercise has been done correctly. An animation in the middle shows how to do the exercise with instructions in the text below it.

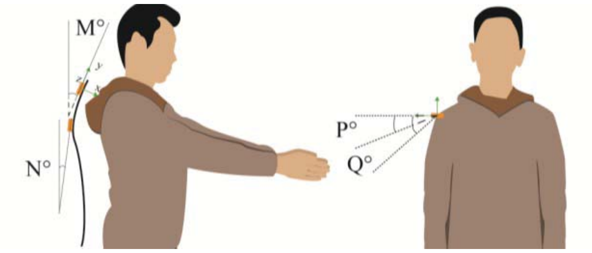

Figure 5. The torso angle is the average of the two angle measurements at points M and N. The shoulder angle is the deviation during movement from angle P at the resting position.

Detection of Poor Postures

Poor postures are detected through considering both the torso and the shoulder angles. The torso angle refers to the angle between spine and vertical plane. The shoulder angle refers to the shoulder girdle elevation angle (see Figure 5) and should not exceed an elevation angle of 45-60° during normal PC work. We settled on some thresholds for these values which have to be considered together for the detection of poor postures as explained below.

If the absolute value of ‘shoulder angle’ is bigger than 20 degrees and smaller than 45 degree or if the sum of the absolute value of ‘shoulder angle’ and ‘torso angle’ is bigger than 60 degree, an error will be recorded. However, when the ‘shoulder angle’ is larger than 45 degrees in the above cases, the user will not be considered to have a poor posture. This is because we do not expect the users to stand up in a fixed position all the time. E.g., they might need to reach out and grab a book in which case it is normal and necessary that the ‘shoulder angle’ should exceed 45°. This should not be counted as an error.

ITERATIONS OF ZUOZI

ZUOZI was implemented on the Samsung Note 3 with the Android operation system. The design went through several iterations following a ‘design through research’ approach with quick design cycles in search for a suitable feedback strategy. Frequent and informal tests with five volunteers who accepted to try out the system regularly provided formative feedback which guided its iterative design and development. Below we explain more how we shaped the current system based on their feedback.

Iteration Design for Shoulder Trainer

The first prototype is just a series of static pictures that show how to do shoulder exercises. (See Figure 6). Arrows indicate how the movements need to be done. Users proposed several improvements: *“Could you add animation to the exercises? I can follow it easier.”*(P2). *“Is it OK to tell me whether I’m doing the exercises correctly or not by the sensors on the vest?”*(P4). The users valued highly their learning cost, the effort they had to put to learn something new for the application. They asked that the interaction should be consistent with popular designs, in order for them to understand and use it easily. *“Maybe you should follow the pedometer apps on the market. That would make it easier to understand.”* (P5). A lot of design decisions were made with the help of users: (1) Changing the notification colors from blue/red to green/red as in traffic lights; (2) Adding animations for exercises guidance (3) Providing instant feedback from the sensors for the shoulder exercises.

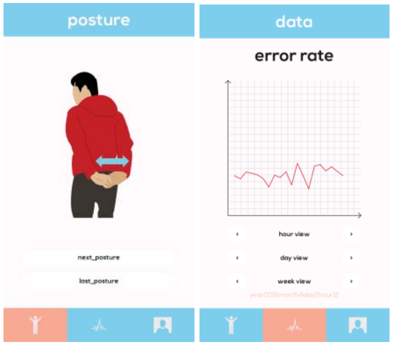

Figure 6. Initial design of shoulder trainer and posture tracking.

Figure 7. A participant going through the usability test.

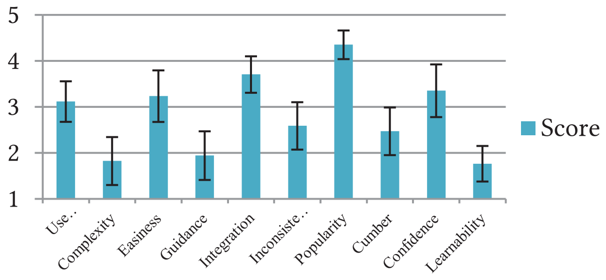

Figure 8. Average score of SUS questionnaires. The lines are 95% confidence interval.

Continuous Shoulder Posture Tracking

As with the shoulder trainer volunteers tried out the application and provided formative feedback. Here we focused on improving the vibration feedback. Earlier work on the understandability of haptic feedback in different contexts has shown that it is difficult to encode complex information using vibration patterns [3,5] and interpreting anything but very simple vibrotactile notifications as vibrotactile requires focal attention by users. Several vibration patterns with different durations (varied from 0.5 seconds to 3 seconds) were evaluated with six users from the target group. Example reactions were: *“I think half a second is not long enough to make me aware if I am working. The longest version (3 seconds) is just good enough because it is comfortable as well as strong enough.”* (P2). *“Don’t try to vibrate immediately if I did something wrong. Maybe I’m taking my cup! Also just tell me once is enough!”* (P1).

To avoid irritation from multiple alarms, a threshold delay of 10 seconds for error indication was introduced after referring a similar study [10]. The duration of the vibration was set to three seconds. This means that if an incorrect posture is detected for longer than 10 seconds the vibration would be activated once. Thus the system will not give an extra vibration if the user continues to perform incorrect posture. If the user corrects the posture the vibration alarm will be reset and activated again when it detects incorrect posture next time.

EVALUATION OF ZUOZI

The evaluation of ZUOZI followed a two-pronged approach. A short-term usability evaluation conducted in context for the shoulder trainer and a one-day field test for the continuous posture tracking. We describe these below.

Evaluation of the Shoulder Trainer

Methods

After the formative evaluations conducted during the iterative development of ZUOZI, we set up a summative evaluation of the shoulder trainer (see Figure 7). 17 participants, students and staff with ages 18 to 30 (*M* = 23.06, *SD* = 2.90, 9 males and 8 females) from our university were invited to a usability test that focused on how able they were to learn to use it for the first time. After being introduced to the system they were asked to carry out a set of exercises 10 times following the instructions on the interface and they would receive its feedback. They then filled in a standard System Usability Scale [9] questionnaire with rating scales ranging from 1 meaning "strongly disagree" to 5 meaning "strongly agree" and were interviewed briefly regarding their overall experience with the system.

Results

The SUS scores are shown in figure 8. The overall SUS was positive (M = 63.53, SD= 9.23). This compares favorably to the industry-wide mean score of 62.1 of 324 evaluations of products using SUS as reported by [9], which is particularly encouraging considering the early research nature of this prototype. The question *"I would imagine that most people would learn to use this system very quickly"* was rated the highest (M = 4.35, SD = 0.61) from the questionnaire. The question with lowest score (*M* = 1.76, *SD* = 0.75) is *"I need to learn a lot of things before I could get going with this system"* which indicates that the efforts made to reduce learning cost were successful.

Field Test of Continuous Posture Tracker

Methods

To evaluate the effectiveness of the system a within subjects experiment in a field setting was carried out; this was a baseline-treatment-withdrawal design [7,13]. Here, the treatment concerns the provision of feedback regarding posture. Concretely the first 2 hours would be the baseline stage in which the shoulder posture was tracked but participants could not receive any feedback from the application (neither visual nor haptic). In the treatment stage which lasted the next 4 hours, participants could check the ZUOZI application for feedback on their performance (if they wanted to) and the haptic feedback on the vest was activated. Both haptic and visual feedbacks were removed in the last 2 hours (withdrawal stage) 25 participants, students and staff with ages 18 to 28 (*M* = 24.08, *SD* = 3.03, 10 males and 15 females) from our university were invited to the field test. Participants wore the smart vest for 8 working hours (excluding the time of lunch, walking, etc.) to collect posture data. We let them could choose wherever they liked to work to disrupt as little as possible their daily routine. They had been informed about the experiment content beforehand and they received a brief tutorial session of the system before starting the experiment. Then the researcher turned on the system and calibrated it to each participant. The participant was also asked to try a few incorrect postures to feel the change in haptic and visual feedback. After everything was set up properly the actual experiment would start. The start time would be recorded by the researcher. Participants were asked to get on with their work as usual; they could walk around for a rest or go to toilet or have short discussions as their daily working routine. When they wanted to leave their seat the vest would be taken off - the data recorded during that time was excluded from the analysis.

To evaluate the overall user experience, we then held a semi-structured interview with each participant which pertained to five main questions: (1) How comfortable is it to wear? (2) How do others react? Do you feel strange to wear it? (3) Describe any interesting events relating to using it. (4) What's your opinion about the feedback? (5) For what reasons might you want to use it for longer?

To gauge the user experience, we used a method called emotional curve based on the Memoline [19]. At the end of the eight-hour trial participants were asked to draw a curve illustrating how their feelings varied over time during the session: The horizontal axis represents time and the vertical axis the valence of the users' emotions. This way we could capture the evolution of the user experience over time. To do so with other instruments like questionnaires would require repeated measures which can be annoying and interfere with the experience measured itself.

Posture data from ZISHI was sampled every 5 seconds. Each sample contained year, month, day, hour, minute, second, the "shoulder angle", the "torso angle" and error. Datasets were stored in a XML file in the smart phone. Around 5000 samples were collected during the 8 working hours for each participant. Irrelevant data, such as those collected when the user went out for a phone call, would be excluded in the data analysis. Erroneous data caused by system errors (for example one participant accidentally dropped the battery) was also excluded.

The results are described into two parts: (1) Quantitative data that reveals statistic findings of the posture angles and occurrences of poor posture, (2) Qualitative data that reveals user's feeling of the experiments and the system.

Quantitative Findings

The measurements of different periods were averaged according to the three different stages. In this section, changes of participants' posture performance during different stages are reported. Raw data and data after tiredness curve calibration are presented below. The raw and calibrated data of occurrences of poor posture is presented in Figure 9.

The average occurrences of poor posture of the baseline stage (B) is 24.91% (SD = 27.61%), of the treatment stage (T) is 17.40% (SD = 13.19%), and of the withdrawal stage (W) is 33.24% (SD = 25.73%). A large drop was observed in the average of occurrences of poor posture in the treatment stage. Then it rose higher in the withdrawal stage. However, from the interviews with users it was found that posture was directly influenced by them getting more tired during the day. For this reason, raw data was transformed by subtracting a tiredness curve representing the temporal variation of posture caused by fatigue.

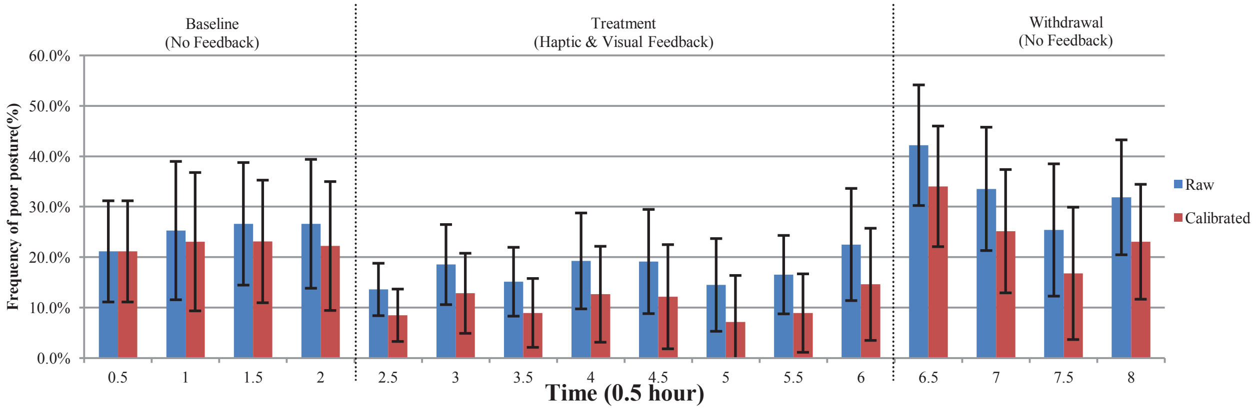

Figure 9. Average occurrences of poor posture before and after calibration. From hour 0.5 to 2 is the baseline stage. From hour 2.5 to 6 is the treatment stage. From hour 6.5 to 8 is the withdrawal stage. The X axis is the time unit of half an hour (8 hours in total). The Y axis is the occurrences of poor posture in percentage. The lines are 95% confidence interval.

	Compare	t-value	p-value
Raw	B vs T	1.483	0.151
	B vs W	-1.239	0.227
	T vs W	-2.907	0.008
Calibrated	B vs T	2.302	0.030
	B vs W	-0.353	0.727
	T vs W	-2.574	0.017

Table 1: Pairwise comparisons of the occurrences of poor posture in different stages for raw data and calibrated data.

According to [12] the muscle fatigue model should be in the form of natural logarithm A tiredness curve should have similar form of function y=α*ln(X), where y is the calibration of occurrences of poor posture and x is the time in the unit of half hour. Parameter α was calculated as the difference between the occurrences of poor posture in the baseline stage minus those in withdrawal stage, divided by ln(16). The function was finally defined as y = 0.0318*ln(x). After removing the tiredness curve, the average occurrences of poor posture in the baseline stage (B) is 22.38% (*SD* = 27.61%), in the treatment stage (T) is 10.71% (*SD* = 13.19%), and in the withdrawal stage (W) is 24.75% (*SD* = 25.73%).

A one-way ANOVA repeated measures ANOVA was conducted to compare the effect of the feedback upon the number of poor postures detected in the three different experiment phases (baseline-treatment-withdrawal) (see Table 1). A significant effect of providing feedback was found when analyzing both the raw data (*F* (2,23)=4.494, *p*=0.023) as well as the calibrated data (*F* (2,23)=4.834, *p*=0.018). Post hoc comparisons found a difference after Bonferroni correction between treatment and withdrawal stages for both the raw data (*t*(24) =-2.907, *p*=0.008) and the calibrated data after removing the tiredness curve (*t*(24)=-2.574, *p*=0.017).

These results provide initial evidence that our system can facilitate decreasing the occurrence of incorrect sitting posture within a single day. Also, we note a gradual decline in the occurrences of poor posture during the day which may suggest that participants learn to keep a good posture by using the system.

We observe a peak of occurrence of poor postures at the start of the withdrawal stage. This peak exists even if we calculated the trimmed mean. We consider this as a rebound after users suddenly received no feedback from the ZUOZI system. We can see in the next 1.5 hour the occurrence of poor postures is recovering to a similar level as the baseline stage. This trend of recovering is more significant if we look at the calibrated data. From this we can infer that users were relying on the ZUOZI system for the feedback of poor postures. After they received no feedback their sitting habits drew back to the baseline level, which showed the importance of the treatment.

Qualitative Findings

The interviews were recorded and affinity diagram were to classify their quotes thematically. Participants commented on the wearability and the social influence after they used the system for a working day.

Regarding **comfort** there were few reservations: *"Yes it is comfortable. Except the circuit is on my back and pushes against the back of the seat."* They felt comfortable using the device, e.g., *"Nobody felt strange because the circuit is covered by the cloth."* (P12)

They became quite conscious of it, and in some cases they realized it **influenced their behaviors** in unexpected ways: *"I would intentionally move less because I thought I was wearing a circuit."* (P5)

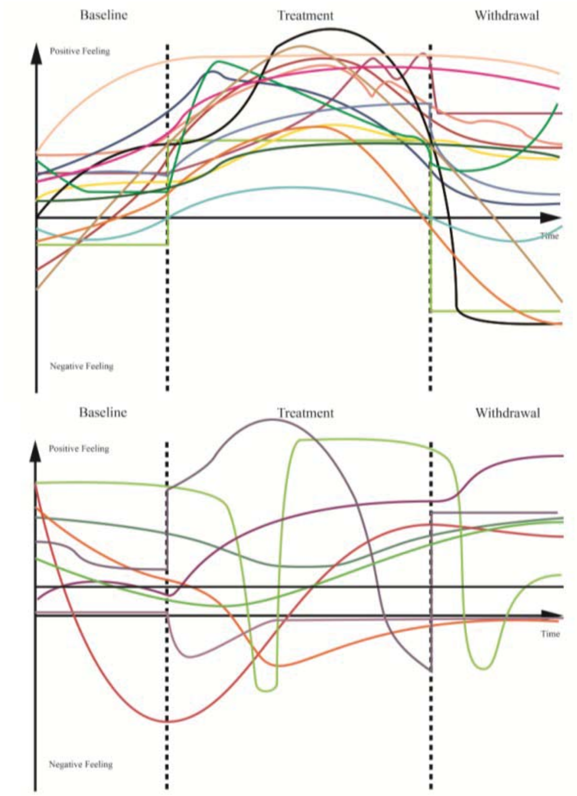

Figure 10. Memolines of participants reporting a positive (top) or negative (bottom) feeling compared to other stages in the treatment stage.

The **frequency** of feedback and the bandwidth of movements that trigger a notification could be reduced: *"Too many vibrations! I just sit lazily for less than 30 seconds!"* (P1)

Aesthetic improvements would make it more attractive to wear, *"If it could be applied to a more beautiful vest, I would like to try it more!"* (P10)

Finally, the motivation for using it depends on how much they have firsthand experience of its **utility**, *"I have had shoulder pain before. So I would like to use it if it's possible."* (P5) or: *"My shoulder has a lot pain. I have problem with shoulder. I had to go to physical therapy in America. If I sit long time without exercises my shoulder will be painful. During the physical therapy the doctors would put tape on you. Although you can ignore vibration, you can't ignore the pain caused by tape."* (P9)

When drawing the emotion lines participants drew curves that corresponded to their interview feedback. Curves were compared by superimposing them on one plane. They appeared to cluster in two groups corresponding to two different patterns that could be found in the reported experiences. The first group describes a positive feeling during the treatment stages with vibration and visual feedback compared to other stages (Figure 10, top). In contrast, the second group describes other stages more positive than the treatment stage (Figure 10, bottom).

For those who reported positive feelings during the treatment phase, they claimed that the vibration gave them quite nice feeling. They felt like they were doing something to improve their working postures. Some also benefited from the visual feedback on the smart phone. However not everyone would check the phone even if they had received vibration feedback.

For those who had negative feeling in the treatment phase, most of them claimed that the vibration was disturbing. Some felt that the system was difficult to attend to all the time. Also it appears that feelings related to their work were integrated in the curve.

DISCUSSION

During the study most of the users reacted to wearable technology as a novelty. They claimed that they would not use a system that was weird or counterintuitive. Smartphone applications and simple haptic feedback were selected for this study to help them get used to the system with most of its parts being quite familiar.

During the evaluation of the shoulder trainer it was noted how users mentioned effort or, as they called it, the 'energy' that they spend every day in order to change or maintain desirable behaviors in their daily lives. They would not be prepared to invest much effort into learning and adapting to a new system. For this reason, we prioritized learnability of the system. Several suggestions for improvement were mentioned. Specifically, for the shoulder exercise, it would be good to indicate the user if they are doing correctly or not in real time. Also animations would work better than simply static pictures.

In the field evaluation of the continuous posture tracker, participants seemed to be very aware of the vest even without any feedback. Wearing the sensors in this way, while new to them, was not something they disliked or resented. Participants held diverse views regarding the intrusiveness of the feedback. One thing they all agreed on was they can easily ignore the feedback when they are in the flow of their work. On the one hand, this is positive as it shows that the system causes little disruption. On the other hand, it could also mean that it may be less effective in real life use: people may be having a poor posture exactly when they are very much absorbed by their work. Longer term field testing in real life use may be needed to examine this issue more thoroughly. Another point worth deeper study is applying activity recognition algorithms, so that the system could detect sitting from other activities/postures, provide precisely error notification and exercise encouragement.

Test participants, especially female, complained about the vest for its aesthetics. However, they praised that luckily with the cloth on the circuit few people noticed that they were trying out a prototype. Making the feedback unnoticeable to others is necessary for the acceptance of the system that aimed at behavior change. Aesthetic improvements upon ZISHI have already been made to address this issue; see figure 11, but this improved design was not ready in time for the field tests. Also, contrary to the tested version which is unisex, this new design addresses female users only.

The field experiment demonstrated that posture is influenced in the expected direction, though further evidence may help consolidate these findings. The data was collected in the course of one day and there is a possibility of reactivity in the results with participants gradually adjusting to the experimenter's expectations. Our results could be strengthened by evaluating behavior on shorter intervals on different days and at different times of the day, to also eliminate the potential confound of tiredness.

Figure 11. Aesthetically redesigned version of the ZISHI upper body posture tracking garment.

CONCLUSIONS AND FUTURE WORK

This paper makes the following contributions: a) it introduces a novel wearable system that can help users carry out shoulder training exercises and continuously monitor their postures b) it presents evidence regarding the usability of the system c) it presents evidence regarding the effectiveness of the system for shoulder posture correction and an evaluation of the user experience during a field trial.

Methodologically the paper combines an interesting set of techniques well known and practiced in the field of user experience design, but not yet applied in the domain of personal health informatics and rehabilitation technology in which they could have a very fruitful application.

Our evaluation also demonstrates a stepwise approach to evaluating systems aiming to support behavior change. First the system is designed in an iterative fashion before summative tests are attempted. Then user attitudes and basic usability are evaluated; success in this case is seen as a precondition for moving to a short field test. The field test is just long enough to show the effectiveness towards motivating behavior change and to evaluate how the system is experienced in context. Such evaluations can be either repeated until the effectiveness of the system has been sufficiently demonstrated, or followed up by longer term field tests to evaluate issues of participant fatigue, dropping out, but also compliance over the longer term with a behavior change goal.

Our system is representative of an emerging class of technologies that allow more targeted and precise self-tracking than current commoditized general-purpose activity trackers. Like many other aspects of our behavior, movement and life, good posture is hard to maintain, but doing so can provide several benefits to users. Developing interactive technologies that can be worn during long hours, and that can help people achieve changes they wish regarding posture, is an area that will attract more research interest and is likely to be used widely in the next few years.

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