Designing an Effective Sonification System to Improve the Musculoskeletal Health of IT Professionals

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ABSTRACT

Over the past century, the amount of people working at desks on computers has greatly increased. Consequently, a lot of people also suffer musculoskeletal disorders as a result of improper posture when working for many hours. We propose a sonification system that supports IT professionals and provides them the proper alerts and reminders to help them maintain proper posture. In this paper, we describe the functions and the testing of a posture correction and break reminders simulator that aims to improve the musculoskeletal health of IT professionals. This study was conducted with 3 IT professionals. An analysis of the results reveals that the system is easy to understand and relevant to the participants, but the sonification is disruptive to hear sometimes, which is a factor to consider in future development of this concept.

CCS Concepts

• Applied computing→Life and medical sciences→Consumer health • Human-centered computing→Interaction design→Interaction design process and methods→Interface design prototyping •Human-centered computing→Interaction design→Interaction design process and methods→User centered design • Human-centered computing→Interaction design→Interaction design process and methods→Activity centered design

Keywords

Computer science; computer audio; human-computer interaction; user interface design; user health; ergonomics habits; musculoskeletal health

1. INTRODUCTION

Over the past few decades, there has been a massive rise in the number of jobs that involve sitting and working at a desk for extended periods of time. The Covid-19 pandemic has greatly contributed to the number of people working and studying from home, and thus ergonomics has become a very important issue that people haven't actively been paying attention to. Because of the Covid-19 pandemic, people are spending much more time working from home and sitting at their desks for longer periods of time. As a result, musculoskeletal disorders (MSD) caused by ergonomic factors such as back posture, wrist posture and flexibility, duration of time spent looking at a screen without breaks, leg positioning, and neck angle can potentially greatly increase if one's work environment isn't properly adjusted; thus, the domain of this paper discusses telepresence and remote work/education/socialization. Desk workers, specifically those that spend extensive hours working at a desk (such as IT professionals) tend to suffer some sort of musculoskeletal disorder. Doctors, such as Physio Andrew Wynd, have noticed "a significant increase in the number of patients suffering neck and shoulder injuries" since the beginning of the pandemic and a lot of low back pain from too much sitting [1]. If these causes of pain are not addressed, it can lead to long-term nerve damage and even the need for surgery [1]. Sunil Garg, an ophthalmologist, has said that staring at a screen all day and not blinking as often (behaviors we exhibit when using computers for long periods of time) tends to dry out our eyes and cause problems for us [4]. This sonification system addresses these ergonomics problems and assists people by providing audio cues to help correct these ergonomics factors to improve the musculoskeletal health of these people who work many hours at desks. The current situation of this problem indicates a trend of worsening conditions as people in general are not very aware of proper ergonomics habits to improve their musculoskeletal health. According to a Facebook survey from the American Chiropractic Association taken in April 2020, 92 percent of chiropractors (out of 213 respondents) said that patients report more neck pain, back pain or other musculoskeletal issues since the stay-at-home guidance (for Covid-19) began [5]. These sorts of problems arise from people spending months working at "sofas and beds and awkward kitchen counters" while hunched over laptops [5]. This, combined with a lot of other factors, such as how people use their laptops, how people sit on their chairs, and level of physical activity simply put a lot of people at risk for chronic problems such as carpal tunnel syndrome, migraines and headaches, stiff necks, back injuries, and more (Irene, 2018). To battle these issues, chiropractors and other health professionals are recommending solutions such as reminders to move every once in a while and adjusting posture to sit correctly. However, while these solutions are helpful in nature, there currently is no method to enforce these suggestions, and thus students and workers could go back to their bad habits. For example, one could initially be sitting with proper posture, but given enough time, this person would regress to bad posture as they would have no system for reminders and corrections. This sonification system aims to correct certain body parts' angles to ensure that proper posture is maintained, and this system also provides notifications for breaks.

2. METHODS

In this section, we will describe the various research questions that are created to determine the quality of the sonification system, and the specific details behind how experimentation was done to determine the answers to the below research questions.

Research Questions:

In order to verify the validity of the sonification system design and to see whether this system would be effective, various research questions were created to help objectively and subjectively determine the quality and effectiveness of the design through both qualitative and quantitative measures. The following research questions bring into question the sound design of the sonification system itself and its efficacy.

(RQ1) Will the users be able to identify the purpose of different sonification cues when those are played?

This is important in determining whether the sound design of the system works in the first place. The results for this question will help in determining whether the sound scheme is too complex for users to comprehend, and qualitative data and feedback from participants helps to determine what sorts of changes would be necessary to improve the concept of the system or the sonification.

(RQ2) Does decreasing amplitude of the sonification cue as the user starts getting closer to the proper posture position help users to adjust the posture quicker and in the right direction?

This is a specific question that will help to determine whether one of the fundamental ideas behind the sound design (being amplitude modulation depending on user input) is a valid sonification output that is intuitive to the user. Quantitative data on reaction time answers this, and qualitative data can help determine why or why not this design is effective.

(RQ3) Will the users find the sonification played as reminders bothersome in case they are in the middle of important work-related matters such as zoom meetings/conference calls?

This research question asks about the practicality of the design when applied to real-life scenarios. In theory, the system could work great, but in real-world applications, where IT professionals encounter a lot of noises throughout their workday, the efficacy of the system may not be the same.

(RQ4) Do users think that the posture tracking sonification system will help them to build a better posture and improve ergonomics habits?

The answer to this research question could help determine the possible long-term effects of the sonification and whether this sort of reminder system would help people improve their musculoskeletal health.

2.1 Setting:

The study took place at the researcher's house. All participants were informed, gave consent, and performed the study procedure on site. All recruitment occurred virtually either through text messages or emails.

2.2 Participants:

For this study, three adult participants were recruited, all of which were either IT professionals or aspiring IT professionals with much experience in the field. Participants were either friends of the experimenter or family friends; however, this did not seemingly bias the experiment, as none of the participants were aware of the experiment beforehand and were encouraged to provide honest feedback. Each participant came to the experiment site at separate times, so the participants were not aware of each other's involvement. Before the study procedure began, each participant was given a briefing of the study activities and then were given a consent form to sign, which gave consent to collect their input and utilize it for analysis in this research experiment.

2.3 Measures collected:

In order to determine the answers to the research questions, the following qualitative and quantitative data was collected from the participants:

- User response time to sonification cues: Response time measures how much time it takes for the user to respond to audio cues. This helps in determining the effectiveness of the audio cues. The faster the users respond and align themselves, the better the design and the easier the system is to use. If it takes too long for the users to respond and align themselves, it's a clear indicator that there's much room for improvement in the sonification design and usability.

- Comments made during the study: This helps to identify the good and the bad of the system design and helps improve the usability of the system by taking direct qualitative input from the participants during the study.

- Post study survey of attitudes: This is a survey that quantifies various factors of the participants' experiences with the simulator, which makes it easier to analyze trends for user acceptance review.

2.4 Simulator:

A custom simulator was made using Java utilizing the Beads and ControlP5 libraries to simulate the input and output of the sonification system. This simulator was in the form of a Processing sketch. The simulator works by providing sonification based on the user's chin-to-throat angle (neck angle), thigh-to-back angle (angle of the back), and the knee-to-leg angle (knee angle). The simulator does this by associating these specified body parts with specific notes; the notes go lower in pitch as the body part angles go closer towards the user's feet, and the sound design is inspired by violin notes. The simulator is broken up into 4 parts: Mode Selection, Initial Setup Mode, Work Mode, and Break Mode. Each of these modes have their corresponding UI controls that allow for manipulation of various internal variables. This section will briefly describe the various modes of the simulator and their intended functions. For the sake of reference, the acceptable ranges of angles are described below:

<u>Chin-to-throat angle: 75-105 degrees</u>

<u>Thigh-to-back angle: 95-115 degrees</u>

<u>Knee-to-leg angle: 90-120 degrees</u>

Figure 1. Screenshot of simulator UI.

Initial Setup Mode:

This mode is intended to be used when the user initially sets up to work. The idea is to provide constant sonification based on the various body angles of the user, but only cease sonification once the user has their corresponding body part within an acceptable range of angles for a duration of three seconds. The sound scheme goes as such: an E note sine wave for the neck angle, an A note sine wave for the back angle, and a D note sine wave for the knee angle. The logic behind these notes was to provide an intuitive association with the system to recognize that the lower the note, the lower the body part that is out of alignment. On top of this, the simulator modifies the amplitude of the sine waves in such a way that an angle further away from the acceptable range of angles for each body part angle increases the amplitude. For example, the user leaning their back too far forward or too far back would trigger an A note sine wave, and the perceived loudness of this sine wave increases the further the user leans away from the 95–115-degree healthy range for their body. This way, the goal of the user becomes to eliminate all noise to prevent cognitive disturbance by aligning their body properly, which directly achieves the goal of improving ergonomics habits.

Work Mode:

Work Mode operates very similarly to Initial Setup Mode in the way that the sonification scheme is the same, however this mode's application and intent is different. Unlike Initial Setup Mode, Work Mode's purpose is not to provide constant sonification, but to only provide sonification only when the targeted parts have been out of their corresponding acceptable ranges for a minimum of 5 minutes. The sonification ceases and the internal timers reset once the user aligns themselves properly.

Break Mode:

This mode provides the user a reminder to stand up and a neck stretch reminder. A text-to-speech (TTS) message is provided once it is time for the user to stand up and take a break, and a looped music sample is played when it is time for the user to stretch their neck. During this neck stretch, the music loop's reverb room size and damping is modified by the horizontal axis neck angle and the vertical axis neck angle, respectively. The greater the angle, the lesser the effects of the reverb. The goal of the user during this stretch break is to stretch their neck twice fully both horizontally and vertically, which is then indicated by increasing clarity of the music loop while they are stretching.

2.5 Wizard of Oz (WoZ) Controls:

Since this system has no technology to receive real-time input from the users through their body, we chose to utilize a Wizard-of-Oz technique to simulate the users' body input into the system. In practice, the researcher would observe the participant during the study and then input body angles into the system and adjust timers accordingly. From there, the system would handle everything else.

2.6 Experiment Procedure:

The experimenter followed the following procedure when conducting the experiment with participants. The experimenter first provided a brief introduction to the study and its purpose. Then, the participants were provided information about the system, what it measures, and its sonification cues. As a part of user training, the experimenter provided the participants a brief rundown of the system sonification and then started the experiment, after encouraging participants to voice their opinions out loud. For the study, the participants were tasked with completing a 20-minute speed typing test on a laptop while working at a desk and sitting on a chair. This activity served to mimic the activity that IT professionals would do. During the study, the researcher collected data about the comments the participants made and measured the time it took for the participants to fix their posture, both at the beginning and at the end of the study. While the participants performed their tasks, the researcher manipulated the GUI of the simulator and set mode and sliders accordingly, in short using Wizard of Oz techniques to mimic the experience of the user providing data to the simulator. At the end of the study, a post study survey was provided to the participants to gather their feedback.

2.7 Shortcomings:

A significant shortcoming of the experiment is that this experiment had to be designed in such a way that too much of the participants' time wouldn't be taken up. Otherwise, participants wouldn't bother to be part of the study if it took around 2 hours for example. Ideally, this study would have benefitted from observing each participant over a course of multiple hours instead of 20 minutes in order to get a better understanding of how the machine affects participants over a longer period of time, and also to allow more instances of correction (since it is to be expected that most participants would tend not to maintain perfect over the course of many hours of observation).

3. RESULTS

In this section, we describe the results of the experiment in response to the research questions. Below is a representation of all data collected.

Table 1: User Response Time to Sonification Cues

Participant #	Time at start of simulation (seconds)	Time at end of simulation (seconds)
Participant 1	20.57	13.50
Participant 2	25.23	12.97
Participant 3	20.83	15.34

Table 2: Comments Made During Study

Participant #	Notable comments
Participant 1	- Annoying to repeatedly hear - Easy to understand - Potentially disruptive during real application
Participant 2	- Sound scheme is somewhat basic, but easy to understand

	- Could be useful in real life
Participant 3	- Intuitive sound design - Break feature is handy - Seems handy in application

Table 3: Post Study Survey of Attitudes Average Score Per Question

Question	Average Score (1 - strongly disagree, 5 - strongly agree)
This sonification will be relevant to the work environment I work in daily	4.33
The operating instructions were clear and easy to understand	5
The sonification amplitude variation was able to guide me properly as well as quickly to get into correct posture during initial setup mode	5
Initial setup mode and work mode targeted the correct areas of my body for the proper posture.	4.66
Break mode offered tracking for optimal number of breaks.	4
This sonification caused minimal interference with my work while monitoring my posture properly.	3.33
This system made me aware of maintaining proper posture during my work.	5
Continued use of this system will help me improve my posture habits	5
Overall experience of using this system was satisfactory.	4

4. DISCUSSION

Based on the results, it seems that the sonification design is satisfactory across the board and is probably a good design, due to the fact that the participants view its sonification scheme as intuitive and therefore easy to master. This system seems to have raised general awareness in proper body posture amongst all the participants and based on how quickly participants have adapted and adjusted their bad posture accordingly, it seems safe to assume that IT professionals would find this system useful. However, participants did find the sounds annoying, although they have indicated that they understand it’s for a good reason. While the developed simulator was made only for research purposes and will not be used for commercial reasons, this observation brings to light an overlooked aspect of the simulator that would be essential to look into for further development: pleasing sonification. There is a chance that users could find the system more adoptable if the sounds being used in the system were to be more sonically pleasing. Disregarding this factor, this system’s intention is to call out users for bad posture, and thus users naturally should encounter less bothersome sounds if they maintain proper posture; looking at it this way, the users are rewarded for maintaining proper posture.

5. CONCLUSION

In conclusion, the sonification system developed for this research is successful in both concept and design, although it’s not perfect. In short, users find the system easy to understand and very useful for their work environment but find the sounds themselves disruptive. Moving forward, making the sounds of the system more pleasing and having longer, multiple sessions with participants would be beneficial in understanding how effective this system is in the long run, which is what this system was designed for in the first place.

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