Wryneck Tree: Designing a Multimodal Interactive System for Sedentary Office Forward Head Postures Correction

Chunman Qiu, Fangfei Liu, Haina Wang, Yueming Xin, Xiaoyu Zhang, and Xipei Ren(✉)

School of Design and Arts, Beijing Institute of Technology, Beijing, China
x.ren@bit.edu.cn

Abstract. Sedentary office workers who lean their necks forward can easily lead to physical health problems such as posture and neck and shoulder pain. The purpose of this study is to integrate health technologies into sedentary office hours to help workers become aware of forward head posture and subsequently promote neck exercises. We have designed the Wryneck Tree interactive system, which consists of three parts: A physical interactive device that mimics the form of a tree, which can monitor forward head posture and subtly change its shape; A digital exergame that motivates users to perform neck relaxation exercises, and a data visualization interface that presents the head posture data. Preliminary user experiments have validated that the interactive system can encourage users to actively improve forward head posture, encouraging us to optimize the Wryneck Tree interactive system further.

Keywords: Neck Forward · Forward Head Posture · Interactive Design · Sedentary Work Environments · Health

1 Introduction

Forward head posture is one of the most common postural problems among office workers who sit for long periods. It is associated with postural imbalance and can increase the strain on the neck and back [1], leading to muscle tension, headaches, dizziness, difficulty breathing, and chest tightness [2]. Sitting at a computer for long periods of time can easily lead to poor posture [3]. Office workers who spend long periods in front of a computer often find it difficult to be aware of their forward head posture, and even if they are aware, it is difficult to maintain the correct posture for long periods. Proper activities such as head rotation, extension, and flexion can alleviate the discomfort caused by forward head posture [4,5]. Therefore, providing opportunities for office workers to become aware of their forward head posture and promoting neck exercises is crucial.

Research has shown that using interactive devices and sensors to monitor users' neck posture and provide real-time feedback or reminders can effectively help users adjust their posture. For example, using smart or wearable devices to provide visual,

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auditory, or tactile feedback can effectively help users maintain proper neck posture [6–9]. Corrective exercises can effectively reduce forward head posture [10, 11], and allowing users to engage in neck relaxation training through games can increase their interest and motivation to exercise [12, 13].

In light of these findings, we have integrated the design of a multimodal feedback monitoring system, game incentives, and data visualization to encourage reflection among office workers. We present the Wryneck Tree interactive system, which consists of three components: The Wryneck Tree interactive device, the Wryneck Tree interactive game, and the Wryneck Tree data visualization interface. The Wryneck Tree interactive system can monitor office workers' forward head posture, provide reminders for posture correction, provide game-based incentives for corrective exercises, integrate forward head posture data throughout the workday, and present it through data visualization to encourage user reflection and action.

2 Design of Wryneck Tree

2.1 Concept of Wryneck Tree Interactive System

Placed in sedentary work environments facing the computer, the interactive system integrates posture monitoring data to provide visual feedback and remind users to adjust their posture when it is incorrect. Every 40 min during work, visual cues encourage users to take breaks and relax while performing neck exercises through the interactive game. At the end of the day, the data on head forward posture and neck exercises are consolidated and visualized on the computer interface. The Wryneck Tree interactive system uses the metaphor of a tree to represent office postures, with a straight tree representing correct posture and a bent tree representing a wryneck posture, encouraging users to become naturally aware of their postural state (Fig. 1).

Fig. 1. Storyboard for the Wryneck Tree interactive system

2.2 Wryneck Tree Interactive Device

Function and Concept of the Wryneck Tree Interactive Device. The Wryneck Tree interactive device is placed next to the computer at the workstation, positioned to the front left of the user (Fig. 2a). During office work, the Wryneck Tree interactive device monitors the user's forward head posture. In its initial state, the device is upright. If the user cranks their neck forward, a light bar at the bottom of the device flashes once and the tree swings from side to side (Fig. 2b), reminding the user to correct their posture. The device will continue to sway until the user maintains the correct posture, at which point the Wryneck Tree interactive device will stop swaying and return to an upright position.

a. The Wryneck Tree interactive device is placed next to the computer on the workstation

b. The light band located at the bottom of the unit will flash once

Wryneck Tree sways from side to side

Fig. 2. Scenarios of Wryneck Tree interactive device

Function Realization of the Wryneck Tree Interactive Device. *Circuit Design of the Wryneck Tree Interactive Device.* The Wryneck Tree interactive device consists of an Arduino UNO board, an ultrasonic sensor, an infrared sensor, a servo motor and a LED strip. The ultrasonic and infrared sensors are positioned at the bottom of the Wryneck Tree device. By measuring the difference between the horizontal distance X from the user's body to the computer screen and the inclined distance Y from the user's head to the computer screen, the degree of forward head posture can be determined. The two distance sensors are placed at an angle. The angle is set at 27 degrees, taking into account the average increase in sitting posture and the typical distance between the user and the device. Each data set consists of two measurements: the first horizontal distance is defined as X1, the first inclined angle distance as Y1, the second horizontal distance as X2 and the second inclined angle distance as Y2. By calculation, the forward head posture distance for each data set is obtained as:

$$\mathrm{Y1cos27^\circ} - \mathrm{Y2cos27^\circ} - \mathrm{X1} + \mathrm{X2} \tag{1}$$

where X2-X1 is used to eliminate interference caused by changes in the user's sitting position (Fig. 3).

The Exterior Design of the Wryneck Tree Interactive Device. The outer shell of the current version of the Wryneck Tree interactive installation, used for experimental testing, has a transparent structure to show the internal circuits and mechanical components in action. The upper part of the Wryneck Tree interactive installation, known as the swinging tree crown, is designed with a three-part segmented structure based on considerations of range of motion. This design allows for smooth movement of the tree body as it swings, and the segments are connected and actuated by springs (Fig. 4a).

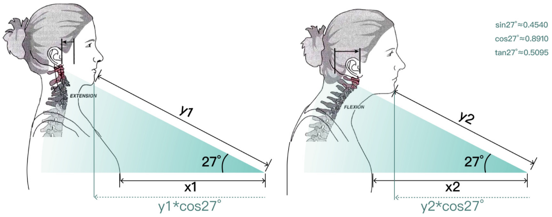

Fig. 3. The Wryneck Tree interactive device monitoring calculation method

Due to the thickness limitations of the manufacturing materials, the thickness of the tree crown increases progressively from top to bottom, creating a nested structure to increase stability during swinging.

The swinging motion of the top of the tree is controlled by servomotors pulling traction cables attached to the top of the tree. If the user is seated correctly, the Wryneck Tree interactive installation will stand upright and the two side cables will remain in a relaxed state. However, if the user adopts an incorrect forward head posture, the servo motors on each side operate at opposite angles (Fig. 4b). As a result, the tethers on each side are pulled to different lengths, causing the Wryneck Tree interactive installation to maintain a stable posture while leaning to one side. After being reminded to correct their posture, the user returns to a normal sitting position. The two servomotors operate to return to their initial state, and at the same time the traction ropes on the tree's crown relax. The body of the tree, assisted by the spring deformation, naturally returns to its upright position.

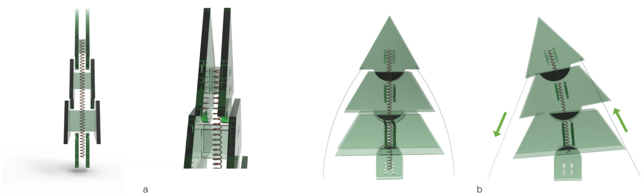

Fig. 4. Appearance of the Wryneck Tree interactive device

Wryneck Tree Interactive Game. The Wryneck Tree interactive game encourages users to perform neck relaxation exercises. When working continuously for more than 40 min, the Wryneck Tree interactive device will swing from side to side to attract the user's attention and draw the user's attention to the Wryneck Tree relaxation pop-up window in the bottom right corner of the work screen. The user clicks on the pop-up window to enter the Wryneck Tree interactive neck relaxation training game. The Wryneck Tree interactive game takes 1 min and the game requires the user to move their neck from side to side to maneuver the character to catch the sun falling from random left and right positions on the top and accumulate points (Fig. 5). The game is implemented using processing and OpenCV with a horizontally tilted camera. The game works by detecting the position and offset of the user's head and determining the speed of the tree's movement based on the offset. If the sun overlaps with the tree, the sun disappears and the score increases by 1; if the sun doesn't overlap with the tree, the sun continues to fall without affecting the score. After 1 min the game ends and the final score is displayed.

Fig. 5. The interface display of the Wryneck Tree game

Wryneck Tree Visualization. At the end of a day's work, users can click on the data visualization module in the Wryneck Tree interface to access the data visualization page. The horizontal axis represents the working time and the vertical axis represents the deviation value of the sitting posture. The higher the deviation value, the more severe the forward head posture. On the corresponding line graphs for each 40-min interval, it is possible to see the number of forward head postures that occurred during this time and the score of the neck exercise game (Fig. 6).

Fig. 6. The interface display of the Wryneck Tree visualization

3 User Test

Based on the functional prototype, we plan to have people who sit for long periods of time use it to investigate whether the Wryneck Tree System can effectively improve the neck forward problem through controlled experiments. At the same time, we hope to explore the experience of using different modules of the Wryneck Tree system through interviews. Specifically, we want to know: (1) The appearance elements, interaction elements, and perception elements of the Wryneck Tree interactive device; (2) The visual elements, interactive elements, and action elements of the Wryneck Tree interactive game; (3) The visual elements, interactive elements, and reflective elements of the Wryneck Tree interactive interface;

3.1 Participants

We recruited 10 volunteers (2 males and 10 females) to participate in the preliminary experiment, aged between 21 and 25 years (M = 23, SD = 1.26), with a mean age of 23 years. We numbered the subjects as "P1, P2…P10". These volunteers are office workers who spend a lot of time in front of a computer, which meets our research needs.

3.2 Setup and Procedure

Before the experiment began, each participant was asked to complete a 20-min control experiment and a 20-min experience experiment with the Wryneck Tree interactive system. The control experiment consisted of two parts. The control group completed a 10-min observation experiment in which participants used the computer to browse text without the Wryneck Tree interactive device. The experimental group conducted a 10-min observation experiment with the Wryneck Tree interactive device installed. We aimed to investigate whether the Wryneck Tree system could effectively improve forward head posture by analyzing changes in the proportion of time spent in a normal posture within 10 min. After completing the control experiment, participants had a 10-min break before proceeding to the 20-min Wryneck Tree interactive system experience experiment. At the end of the experiment, a semi-structured interview was conducted to address the research questions. The specific steps of the experiment were as follows.

1. Sign the informed consent form.
2. Use the computer for 10 min to browse text without the Wryneck Tree interactive device (the device was not placed on the desktop). (control group)
3. Use the computer to browse text for 10 min with the Wryneck Tree interactive device installed. (test group)
4. 10-min relax.
5. 20 min of Task Flow operations, completing the Wryneck Tree training game and exploring the data visualization.
6. Semi-structured interview with each participant.

3.3 Data Collection and Analysis

During the experiment, we collected qualitative and quantitative data, in the data collection for controlled experiments, we recorded the duration of head forward posture behavior of participants in the control group and the experimental group, using the statistical software SPSS to analyze the data collected from the control group and the experimental group to the proportion of normal posture within 10 min, the data were analyzed by repeated measures t-test to explore whether the Wryneck Tree Interactive System is effective in improving the neck forward tilt problem. To ensure accurate recording of the duration of head forward behavior in the experimental participants, simultaneous observational recordings and video recordings of the participant's sides were made at the same time during the experimental process, and the total duration of the participants' head forward tilt.

In terms of qualitative data, participants' evaluations of their experiences with the Wryneck Tree interactive system were captured through semi-structured interviews.

The interviews were recorded in the form of audio recordings and notes, and the audio recordings were later converted to text for subsequent coding and analysis, in order to understand the participants' perceptions, needs and suggestions about the system from their perspective.

4 Results

4.1 Quantitative Findings

Repeated measures t-test showed that participants' head forward posture duration was significantly shorter after using the Wryneck Tree interactive device (M = 69.90, SD = 68.501) compared to the control group who did not use the Wryneck Tree interactive device (M = 168.70, SD = 124.521), with a p-value of 0.035, which is lower than the significance level of 0.05 (Fig. 7). This suggests that after using the device, participants were able to correct their forward head posture more effectively and reduce the duration of poor posture.

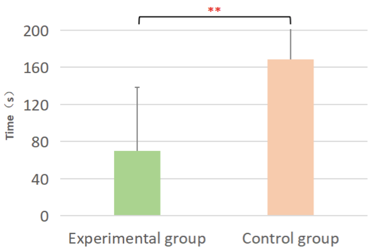

Fig. 7. Data Analysis Results

4.2 Qualitative Findings

Through qualitative analysis and coding of interview data, we identified three themes that encompassed participants' perspectives on user experience, their specific needs and requirements for certain features, as well as suggestions for design improvements.

Perspectives on User Experience. 70% of participants expressed positive attitudes towards the use of the system. Participants described their feelings of use in terms of personal fulfilment, proof of competence, monitoring and anxiety. For example, "The monitoring of the device subconsciously makes me more aware of my posture, even if no cues are triggered." (P2) "I would like to get a higher score in the game." (P4) "The device wobbling causes me anxiety as I don't want it to move, so I will consciously sit upright." (P7) This suggests that the system increased the participant's attention to self-posture to a certain extent, and was effective in helping the participants to reduce neck leaning behaviors through supervision, fun, and satisfying the sense of personal achievement.

Meeting Autonomous Needs. Participants expressed a desire to have the autonomy to choose accessories to decorate the product according to their personal preferences and different holiday requirements. For example, "During holidays, I can use accessories to decorate the small tree, like having a Christmas tree for Christmas." (P4) "It would be more interesting if I could choose the type of tree for the installation." (P5).

Challenges. Participants offered some helpful suggestions for the Wryneck Tree. They pointed out that the placement and appearance of the game prompt could affect the user's perception. Specifically, some participants noted that the sudden appearance of the prompt in the lower right corner, like a pop-up window, made it easy to ignore. Participants felt that the visualization interface was a little difficult to understand and that the information was not clear enough, indicating the need to improve the design of the visualization to ensure the accuracy and clarity of the information conveyed. Furthermore, they recommended taking into account individual work habits, such as allowing for personalized adjustments of sensitivity. For example, one participant mentioned that being too sensitive can sometimes discourage them from taking a break. (P3).

5 Discussion

The integrated interactive system described in this paper combines multimodal feedback monitoring reminders, game-based motivation, and data visualization to promote reflection. We conducted a comprehensive evaluation of the Wryneck Tree interactive system and discussed its innovative aspects and limitations.

The experimental results indicate that participants are able to effectively correct forward head posture and reduce the duration of poor posture. Participants showed a positive attitude towards using the Wryneck Tree interactive system. The innovative aspects of the Wryneck Tree interactive system encompass a multimodal approach, real-time monitoring, and gamification. The adoption of a multimodal approach allows the system to integrate real-time monitoring, gamification and data visualization, thus providing a novel and comprehensive solution to the problem of forward head tilt in sedentary office workers. The real-time monitoring feature tracks users' neck posture continuously, offering instant feedback and reminders to enhance user awareness and prompt timely posture correction. The integration of gamification encourages users to engage in neck exercises through interactive games, making the process more appealing and enjoyable, thereby motivating users to adopt healthier habits.

The Wryneck Tree system also has certain limitations. Firstly, there are individual differences in user responses to reminders, gamification, and visualization, which might result in variations in the system's effectiveness among users. Secondly, user engagement is a concern; although gamification can enhance engagement, users may lose interest over time. To address this issue, the introduction of incentive mechanisms, such as enhancing the social attributes [14] of the game, could further motivate users. In terms of future design and development of the Wryneck Tree system, we are considering enhancing the alignment between the system's functionality and specific usage scenarios. For instance, in the hardware design, we need to consider the relationship between different office space layouts and sensor placement forms. We are also considering enhancing the personalization and adaptive feedback of the interactive system, such as providing tailored interventions and support based on individual user characteristics, such as neck strength or flexibility.

6 Conclusions

In this paper, we propose the Wryneck Tree interactive system, which aims to address the issue of sedentary office workers with forward necks. This system offers real-time monitoring, game incentives, and data visualization to comprehensively tackle the problems faced by sedentary office workers. Our preliminary experiments examine the user experience of the Wryneck Tree interactive system and provide directions for improvement. In the future, we plan to make adjustments based on test feedback and conduct user research to verify the effectiveness of the system. We look forward to further in-depth research to help us develop new health and welfare projects.

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