Actuating a Monitor for Posture Changes

Joongi Shin
Korea Advanced Institute of Science and Technology
jgshin@kaist.ac.kr

Uichin Lee
Korea Advanced Institute of Science and Technology
uclee@kaist.edu

Woohyeok Choi
Korea Advanced Institute of Science and Technology
woohyeok.choi@kaist.ac.kr

Daniel Saakes
Korea Advanced Institute of Science and Technology
saakes@kaist.ac.kr

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Abstract
The position and orientation of a monitor affects users' behavior at their desk. In this study, we explored and designed six types of interactions between an actuated monitor and a user to induce posture changes. We built a virtual monitor that simulates the motions of an actuated monitor and slowly moved in the opposite direction of unbalanced sitting postures. We conducted an explorative study with eight participants. The study showed participants' responses and step by step posture changes toward balanced sitting postures. As contribution, we share considerations for designing monitor actuations that induce posture intervention.

Author Keywords
Human robot interaction; Ergonomics; Behavior intervention

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces: Ergonomics, Interaction styles

Introduction
A monitor affects people's behavior at their desk. As people read from the screen, they adjust their posture to a comfortable angle and distance. Based on this relationship, we expect diverse posture changes from users by actuating their monitor.

Figure 1: We conducted a formative study. The researcher hid behind the fake wall and moved monitor to explore monitor motions that induce aimed posture changes.

In this study, we explored six interactions between an actuated monitor and a user that induce intuitive posture changes from diverse unbalanced postures. We designed movements that using a monitor in an unbalanced posture is increasing uncomfortable, but comfortable in a balanced posture. We conducted an explorative study to observe 1) how users respond to a moving monitor and 2) how a monitor needs to move to induce aimed posture changes.

Related work

Posture intervention

Diverse stimulations have been studied for posture changes. Haller et al. tested three different types of notification systems such as graphical, physical, and vibrotactile feedback that alarm users to adjust their sitting posture [7]. In these interactions, the participants needed to learn that notifications were cues to correct their posture. In contrast, our system modifies desk environment to fit only intended sitting posture and induce posture changes intuitively.

Posture awareness has been studied to encourage posture corrections. Jaimes and Liu developed a posture documentation system that presents the ratio of unbalanced sitting posture [5]. In another study, BITAIKA, a system visualized users' back angle in real time and overlapped it on the healthy angle to encourage posture correction [4]. In both studies, the posture changes were solely dependent on participants' will. In our case, a monitor moves to provide good readability only to an aimed posture, which would prevent ignoring interactions or making arbitrary posture changes.

Actuated desk environment

Multiple studies have explored the interaction between users and actuated monitors to improve work performance. In the study, Living Desktop, an actuated monitor, keyboard, and mouse recreated the desk landscape to improve work efficiency [1]. Liu and Picard, studied presenting subtle expressions through an actuated monitor stand for anthropomorphic value in the interaction [6]. Both studies explored the interactions between actuated monitor and users, but their focus was not related to posture changes.

Breazeal, Wang, and Picard, studied the influence of posture on affective state and its relationship to work performance [2]. They used a robotic monitor to present three different heights of the monitor and made participants to pose neutral, slumped, and upright sitting postures. This study showed the use of different monitor heights and angles for maintaining different poses, but they did not move the monitor in real time to change participants' posture. In our study, we observed the real time interactions between a moving monitor and users in the field of posture intervention.

Formative study

We conducted a formative study with six participants to map the relationship between monitor movements and unbalanced postures. In a lab setting, a researcher hid behind a cardboard wall and held a 24 inch monitor. We asked participant to read a text on the monitor in unhealthy sitting postures. Then, the researcher slowly moved the monitor (Figure 1), and the participants changed their posture to regain readability on the text.

The study showed that the direction of monitor movements need to be properly matched with each unbalanced sitting pose. For instance, when the researcher raised the monitor, participants who leaned forward, straightened their back. On the other hand, other participants, who leaned backward while sitting on the edge of the seat, leaned backward even more. From the results, we categorized unbalanced poses into 4 types: lean forward, lean backward, not facing front, and tilted head (Figure 2).

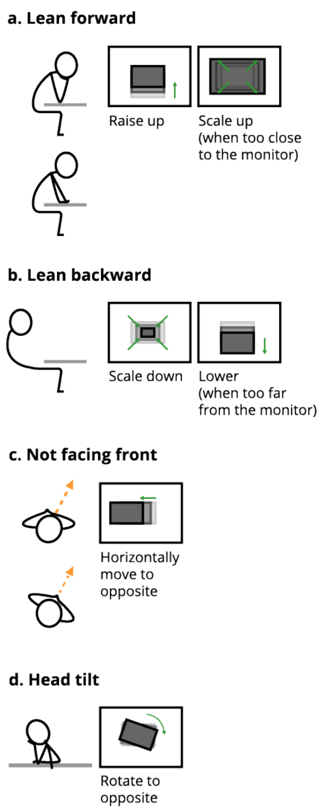

Figure 2: The different types of unbalanced postures and monitor movements to induce correct sitting posture.

Design

Based on the unbalanced postures, we designed six different motions; raising up, raising down, horizontal movement, rotation, moving forward and backward (Figure 2). The key idea is to move the monitor so that the position and orientation of user's head would match with the target posture. For example, when users lean forward, their head is positioned lower than the straight sitting posture. Therefore, the monitor moves upward until the users cannot read the contents without raising their head and sit up straight (Figure 2a).

User study

Apparatus

Since our main purpose is to observe people's reactions without any physical contact, we built a virtual monitor that simulated the movements of an actuated monitor through the wizard-of-Oz technique. Through informal tests, we set the movement speed of the virtual monitor as 1.8 mm per second, which people could both read text and sense the movements. The forward and backward motions were implemented as changes in scale.

Our system has two computers connected over a network. We used one as a remote controller for manipulating the virtual monitor and the other as a receiver for rendering the virtual monitor (Figure 3). The receiver is connected to a 24 inch and a 4k monitor (65 inch). It duplicates the screen of the 24 inch monitor and displays it as a 24 inch virtual monitor on the 4k monitor. The remote controller displays the current state of the virtual monitor and moves it when researchers press designated keys on a keyboard.

Procedure

We conducted an explorative study to observe participants' responses and identify design considerations for building an interactive robotic monitor. We selectively recruited 4 male and 4 female university students (mean age: 22.87, SD: 2.35) who spend most of their time at their desk and usually sit unbalanced during their work. These conditions were to observe multiple interactions during the study. The main study was conducted in a lab setting that was divided by a one-way mirror (Figure 4). The researchers sat behind the mirror to observe participants' sitting posture and manipulated the virtual monitor.

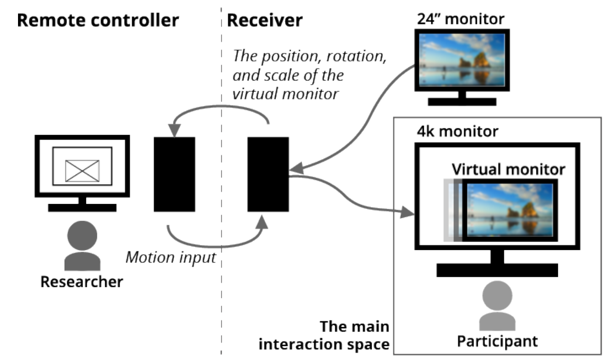

Figure 3: We built our prototype with two desktops to render and control a virtual monitor.

The process of the study is shown in Figure 5. The study was conducted with one participant at a time for about 2.5 hours. We set the height of the virtual monitor same as the participants' monitor height at their room. Using our prototype, participants performed two common desk related tasks; summarizing a text and watching a video. Each activity lasted about 50 minutes and ended with a short questionnaire. We concluded the study with a 30 minute interview using the questionnaire and the video documentation of participant's behaviors.

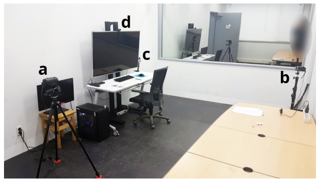

Figure 4: In a lab environment, we placed camcorders to document posture change from side (a), back (b), and front (c). We also put a webcam on the 4k monitor as a fake sensor (d).

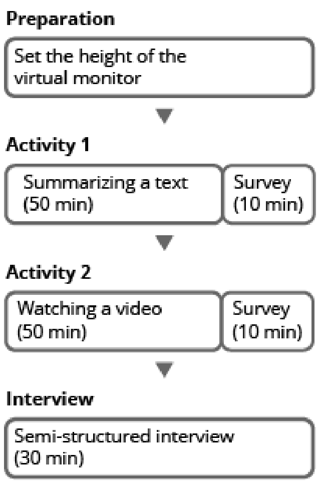

Figure 5: To avoid learning effect and fatigue, half of the participants started with the Activity 2. We asked the participants to bring text and video materials for each activity to encourage them to perform naturally.

The general interaction during the study was in four steps. First researchers observed unhealthy posture. Second, they manipulated the virtual monitor to induce posture correction. Third, the participants responded to the motion. Finally, the researchers moved the monitor back to its original position. We intentionally reset the position of the monitor to observe multiple interactions within a limited research time.

Result

We tested and observed all six interactions that were triggered by all four categories of unhealthy poses, and 7 out of 8 participants experienced 3 to 4 different interactions.

The purpose of the study was not validating our designed interactions but to observe the participants reactions on the interactions. Therefore, we focus on their posture changes as they interact with the virtual monitor.

Most movements made the participants to correct their posture in directions that we expected (Figure 6). They followed the virtual monitor in the order of moving eyes, neck, and back. When the monitor moved upward as the participants leaned forward, the participants followed the screen with their eyes first. As the monitor kept going higher, they tilted their head backward to look up and eventually straightened their back as tilting head was uncomfortable.When the participants were too close to the monitor we scaled up the monitor. As a result, they leaned backward when the contents were too big to read at a close distance. The monitor scaled down when the participants sat on the front edge of the chair and leaned backward. They stretched their neck forward then raised up their torso to sit straight or lean forward. Leaning forward was corrected by resetting the scale.

During the video watching activity, participants rarely interacted with the keyboard and could turn their body to left or right. When the monitor moved to the opposite direc-

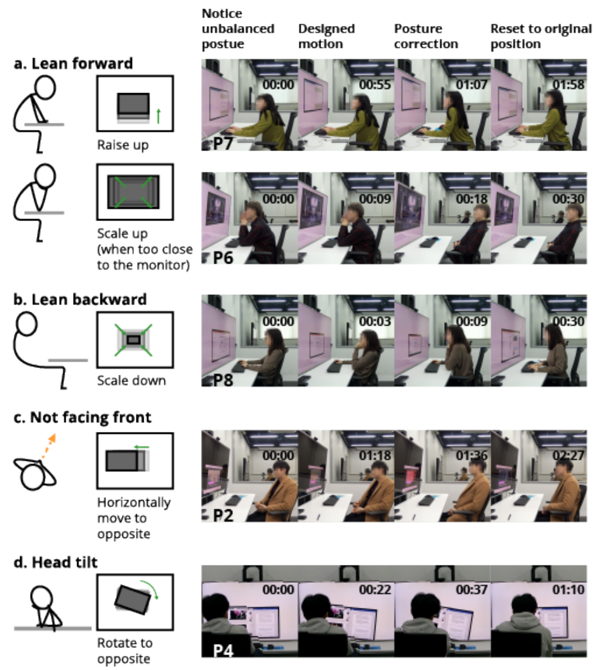

Figure 6: The 5 types of successful interactions (left), and the participants' posture changes in steps (right).

tion, they followed the monitor with eyes first then by turning their head. Eventually, they turned their body as well to face front or to face the monitor. As we reset the monitor to center, both of their head and body faced the monitor in front. When the monitor rotated opposite to their head tilt, the participants stayed still until they could not read the contents. Then, they either tilted their head back to normal or to match the angle of the monitor. In the later case, the participants straighten their neck as the monitor reset its angle. However, sometimes the interactions failed to correct a posture. For instance, lowering the monitor worked only once for participant 6 and failed at the rest of attempts.

Although we did not intend reseting motion to be a major interaction, the participants' responses were worth to consider. While resetting from the horizontal motions and rotation did not have negative effects on maintaining a correct posture, resetting from the raising up motion and scaling influenced some participants to go back to their previous unhealthy posture. For instance participant 3 leaned forward as the monitor moved downward even when the monitor was still above the ergonomically correct height (Figure 8).

The duration of maintaining the posture varied based on how participants changed their posture. The most distinctive one was sitting up straight from the leaning backward while sitting on the front part of a chair. Some participants raised their body, moved their pelvis closer to the back support, and leaned against the back support to sit straight (Figure 7a). By sitting deep in the chair, the participants maintained the posture without putting stress on the back. Other participants only raised up their body and did not reduce the gap between their pelvis and the back support. As a result, they could not support their upper body and went back to the previous unhealthy posture (Figure 7b).

Figure 7: Different types of posture correction. Some participants repositioned pelvis closer to the back support (up) while the others only corrected posture and went back to unbalanced posture (bottom).

Discussion

The study showed that the monitor actuation can induce intended posture changes from users, and we observed multiple considerations for improving the interactions.

Mental model about monitor intention

As we did not reveal the purpose of the study, three participants misunderstood the interaction and thought that the monitor was trying to support their current posture. For instance, participant 8 commented "I thought it was supporting my posture. But it was moving in the opposite direction

Figure 8: Posture changes during reset. Some participants maintained their changed pose (bottom), the others went back to previous pose as the monitor reset its state (up).

(p8 was leaning forward and the monitor moved upward)." The participants believed that the interaction was triggered by the mismatch between their posture and the state of the monitor. Therefore, most interactions were ambiguous for them since they needed to change their posture even when they could read contents well. Based on the potential of misinterpretation, we believe how to clarify the intention of interaction would need to be considered.

Understanding current posture

Among the participants who interpreted the interactions as posture correction, most of them thought their posture was unhealthy when the monitor moved. On the other hand, some participants did not realized that their posture was unbalanced and confused about the interaction. For instance, participant 2 commented "There was a moment that I was sitting correctly but the monitor moved upward (p2 had forward head posture)." As p2 already understood that unbalanced posture causes the interactions, he kept trying to straighten his back a bit more instead of his neck angle. Based on their responses, we believe that how users might see themselves need to be considered for detailed posture intervention. In our case, specifying the joint that users need to focus would be one solution.

Task type and potential distraction

The participants' sensitivity to the movements were different between tasks. As reading and typing required focusing on each word, they commented that it was more intrusive than watching a video. On the other hand, videos were already too dynamic to notice the motion. Participant 4 replied "When watching the video, my tolerance to the motion was big, so I moved after the monitor was tilted a lot." Although we intentionally reduced readability by moving the monitor, the distraction should be minimized to avoid causing fatigue. Therefore, we argue that the motion parameters would need to be controlled between activities and consider detecting opportune moment (e.g. task switching moment) to balance obtrusiveness in the interaction.

Conclusion and future work

We developed novel interactions with an actuated monitor to induce posture changes. The study validated that movements of a monitor can correct diverse unbalanced postures. Although software based interactions work well for zoom [3] and rotation, they can not achieve the vertical and horizontal range that we found. Therefore, we propose to build a full robotic monitor and develop guidelines for effective yet less intrusive interactions.

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