Indirect Posture Correction System without Additional Equipment using Display Content Rotation

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Abstract: The poor posture of office workers who engage in PC work is a problem. Poor posture may cause musculoskeletal disorders. In previous studies on the posture correction system, there are some problems. One of them is that the posture correction system may interfere with the tasks of office workers. There is a posture correction system which does not interfere with the tasks; however, it requires large equipment. In order to solve these problems, we proposed a system that corrects the posture of office workers by rotating the content in the display. This is a method that rotates content in the opposite direction of head movement. We expect that users unconsciously move their head to look at content. We evaluated our porposed method with 2 user studies. User study 1 was conducted to verify whether the angle of the spine changed by rotating the display. It suggested that rotating the dislay induce the head to adjust laterally, not longitudinally. In study 2, we succeeded in moving the direction of the angle of spine of experimental participants to the right by an average of 1 deg by rotating the content right. Thus, we showed the possibility of posture correction without large-scale equipment.

1 INTRODUCTION

In the present working environment, many office workers work with a PC on a desk. It is suggested that continuing to work while exhibiting poor posture leads to musculoskeletal disorders (van DieËn et al., 2001; Lis et al., 2007). Thus, there is a social need to develop systems to correct posture.

In existing research on the posture correction system, there are two methods: direct posture correction and indirect posture correction. Direct posture correction is a way to inform office workers of their poor posture and thus improve it. Indirect posture correction is a way to change the surrounding environment of office workers and correct their posture without them being conscious of their posture.

A typical example of direct posture correction is a system by notification. Desktop notification of PC and the vibration of a vibrator mounted on clothes are used to inform office workers of their poor posture (Ishimatsu and Ueoka, 2014; Kim et al., 2016; Tanaka et al., 2015; Ying Zheng and Morrell, 2010; Salvado and Arsenio, 2016). However, frequent notifications may interfere with work and degrade task performance (Adamczyk and Bailey, 2004). Some studies have focused on preventing interference with work using a flower avatar (Hong et al., 2015a; Hong et al., 2015b). It is presumed that the effect in the posture correction is reduced because of less opportunity to give feedback to office workers. In other words, workers are less likely to recognize their poor posture and correct it. Since every time the system corrects their posture, it interrupts their task performance, and the degradation of the task performance becomes a problem. There is eye-head coordination (Morishima et al., 2016) in human visual characteristics. Eye-head coordination is the phenomenon where the eyeball rotates and the head rotates following it when what we look at moves parallel to it. That is, the head rotates following the parallel movement of what we look at. Similar phenomena can be seen in previous studies of indirect posture correction (Shin et al., 2019; Shin et al., 2018). These approaches tried to adjust the display gradually when the worker's posture becomes poor. The display adjusts in a direction opposite to the direction in which the worker's posture becomes poor. Then, workers unconsciously follow the movement of the display. As a result, the workers'posture improves. Their heads follow the parallel movement of what we look at and move in the same direction. The behavior of following the display is induced by changing the surrounding environment of the workers. Then their posture is corrected. They unconsciously follow indirect posture correction with-

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out this interfering with their tasks. The method of attaching a robotic arm to the back of a display is used (Shin et al., 2019). In other research, a work display is displayed in a large display many times larger than the work display, and this is moved within the display (Shin et al., 2018). However, these methods are not suitable for office environments because they require the introductions of large-scale equipment such as robot arms and huge displays.

Thus, direct posture correction may interfere with tasks. Though there is no risk of task interference in previous works of the indirect induction method, there is the concern that a giant actuator is necessary and the introduction cost is large. Thus, in this paper, we propose an indirect posture correction system without introducing new large equipment.

In order to solve these problems, we proposed a system that corrects the posture of office workers by rotating the content in the display which they use in their office. We expected that by rotating the content, their head would adjust in the direction of the rotation and the angle of the spine would become better. It was thought that we could achieve indirect posture correction without introducing additional large equipment by using displays that are already available in a general office.

Previous studies have shown that by adjusting the displays, the head adjusts along with it. However, it is not clear whether the head rotates when the display rotates. We considered that the head does not adjust by rotating content in a display unless the head adjusts by rotating the display. First, we experimented to verify whether display rotation causes head adjustments. Next, we experimented to verify whether content rotation causes head adjustments.

The contributions of this paper are as follows.

- This paper proposes an indirect posture correction system to change the head position of office workers by rotating the screen without using large equipment.
- It is verified that the angle of the spine changed following the horizontal rotation of the screen and it is possible to laterally correct posture.
- It was demonstrated that posture correction was possible even by rotating the content in the display.

2 PROPOSED METHOD

We proposed to rotate the content in the display to correct the posture of workers using indirect posture correction without large equipment. We considered

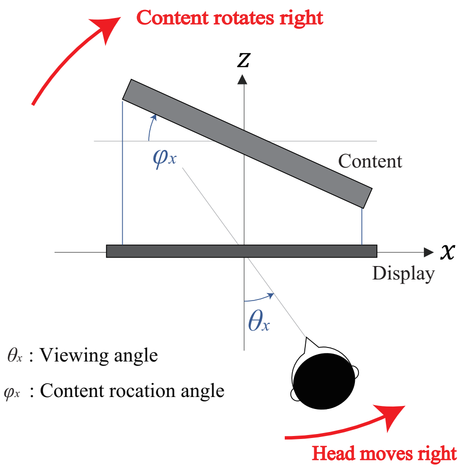

Figure 1: Schematic diagram of the proposed method. When the head moves right, the displayed content rotates right.

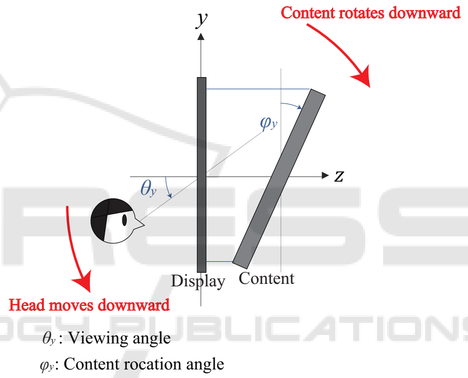

Figure 2: Schematic diagram of the proposed method. When the head moves down, the displayed content rotates upward.

that when what we look at rotates, the head adjusts like the eye-head coordination.

A vertical view of worker and their display is shown in Figure 1. We define θ_x as the angle between a plane perpendicular to the display and perpendicular to the horizontal plane and the viewing direction of the head of a worker. We define ϕ_x as the rotation angle of content. The rotational direction of ϕ_x is the opposite direction of θ_x. A side view of worker and their display is shown in Figure 2. We define θ_y as the angle between a plane perpendicular to the display and parallel to the horizontal plane and the viewing direction of the head of a worker. We define ϕ_y as the rotation angle of content. The rotational direction of ϕ_y is the opposite direction of θ_y. It is thought that as the rotated content is displayed, the head also moves in the direction of the content rotation. We considered that controlling the rotation angle of the content would move the head position, and the inclination of the spine of workers would change; thus, posture can be corrected.

A worker sits on a chair and the spine tilts backward. Then, the entire content in the display rotates gradually upwards. The worker unconsciously moves their head upwards to try to look at the content from the front. As a result, the spine tilts forward and has better posture. The system detects posture correction, and the content rotates back to the original orientation. Using such a control system in the lateral direction, workers can always continue to work in a good posture.

First, it was necessary to verify that the spine tilts by the rotation of the display to realize our proposed method. The rotation of the content was different from the rotation of the display. The content was not actually rotated but was displayed to workers as if it really rotated. Workers may not be able to recognize the display change as the rotation of the content. Therefore, it was considered that the relation between the rotation of the visual target and the angle of the spine cannot be verified. To begin, we verified whether the angle of the spine changes by rotating the display, not the content. The following should be verified.

- Rotation of the display causes the spine to tilt.
- Rotation of the content in the display also causes the spine to tilt.
- Rotation of the content in the display can correct the worker's bad posture.

In this paper, we verified the 1st and 2nd items as the first step of this research.

3 USER STUDY 1

As described in the previous section, we conducted the user study to verify whether the angle of the spine of workers changed by rotating the display. And we also verified whether the rotation of the display did not reduce the task performance of workers.

This study was conducted with a within-subject design. Participants were asked to solve a task in the display while the display itself physically rotated. We set three conditions for the direction of rotation (right rotation, up rotation, no rotation). The angle of the spine was measured. The task result was measured as task interfere level. These were compared among conditions. Three participants joined in this study.

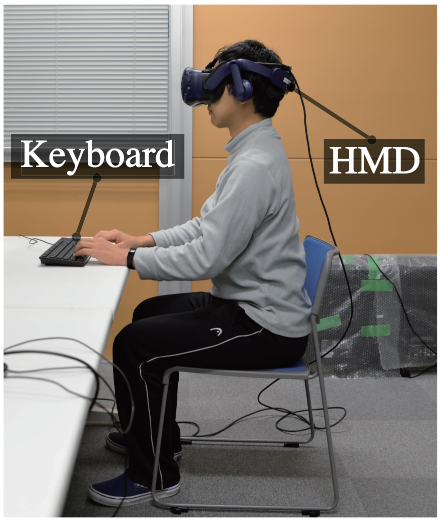

Figure 3: Participants used HMD and a keyboard on the desk in the experiment.

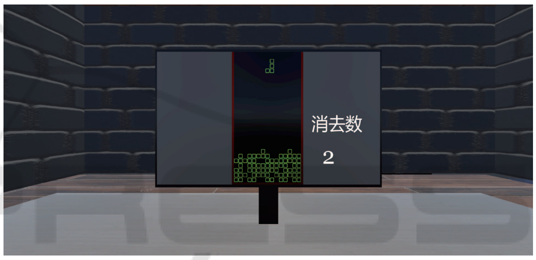

Figure 4: 24-inch display is placed on the desk. A tetris task is displayed at the center of the display. Task performance is displayed next to the play area.

3.1 Experiment Design

The experimental environment was created in Virtual Reality (VR). Experiment participants attached Head Mounted Display (HMD)(Figure 3). We used VR to place objects relevant to the experiment because visual and auditory information which is unrelated to the experiment can be blocked from participants. A desk and a 24-inch display were placed in the virtual environment (Figure 4). The distance of the display to the participants is about 55 cm. The position of the HMD is measured by an infrared camera. The position of the head of participants in the VR was changed according to the HMD position. It was considered that necessary conditions for verification were realized because participants can see the display and the visual field changes according to the head position in VR. VIVE Pro (HTC) was used for HMD. The refresh rate was 90 Hz.

The flow of the experiment is described below. Participants sat on a chair in a comfortable position

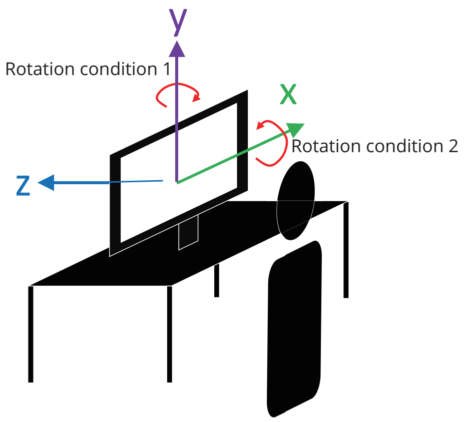

Figure 5: Rotate the display in the direction of the y-axis in condition 1. Rotate the display in the direction of the x-axis in condition 2. No rotation in the display in condition 3.

and were told to solve the task shown in the display. As the task was shown on the monitor, we selected Tetris (The Tetris Company,). Tetris is a famous and easy to operate game. This was chosen because we thought that participants could concentrate on a task and see a large area of the display with this task. To do this Tetris task, participants only used the arrow keys of the keyboard placed in front of the participants. First, participants wore HMD and practiced the Tetris task for two minutes. Next, they solved the Tetris task for 15 minutes. The display did not rotate for the first 10 minutes to make participants concentrate on the task. During the last five minutes, the display was rotated with one of the three conditions described below. After 15 minutes, participants removed the HMD and answered the questionnaire about task interference.

The experimental conditions were 3 types: positive y-axis rotation condition (right rotation), negative x-axis rotation condition (upward rotation), and no rotation condition (Figure 5). The y-axis negative rotation (left rotation) was excluded from the conditions considering the symmetry. Negative x-axis rotation (downward rotation) was also excluded from the conditions because it was considered that it was not necessary to guide the head downward to correct the posture. These three conditions were conducted for each participant. The order of the conditions was counterbalanced. For each direction, the rotational speed was 0.1 deg/s, and the maximum rotational angle was 30 deg. The rotation speed was chosen to be low enough so that participants were unconscious of the rotation of the display. The maximum rotational angle was determined so that participants could recognize the rotation of the display while it rotated at a low speed.

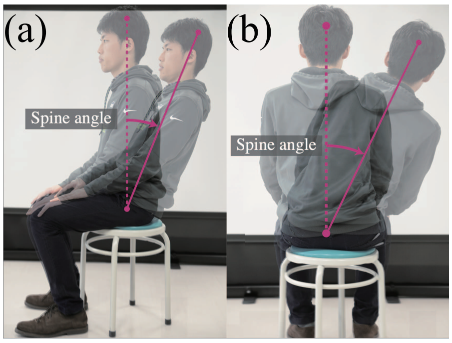

Figure 6: (a) We calculated the forward and backward angle of the spine in the upward display rotation condition. (b) We calculated the right and left angle of spine in the right display rotation condition.

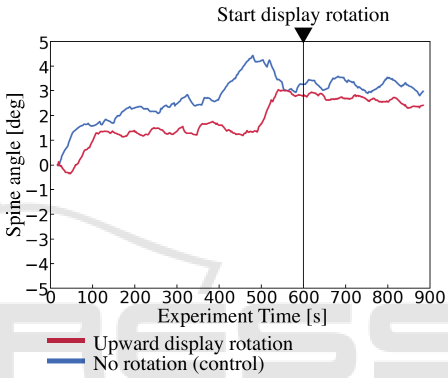

Figure 7: Forward and backward inclination of the spine with upward display rotation and no rotation conditions. Red line denotes upward display rotation and blue line denotes no rotation.

The head's position was obtained from the HMD position measured by the VIVE Pro base station. The accuracy and precision of position tracking in the HTC VIVE is under 0.2 mm (Niehorster et al., 2017). We calculated the angle of the spine from the head position of the participants. We considered the initial spine angle was perpendicular to the horizontal plane. The angle from the initial position was calculated as shown in Figure 6.

As an objective index of task interference, the number of deleted rows of the Tetris task for 15 minutes was obtained and defined as the task performance. In order to obtain a subjective index of task interference, participants were asked to answer a questionnaire. The method of answering the questionnaire was the 9-grade evaluation.

3.2 Result

An example of a displacement of the angle of the spine of a participant with a display rotating upward

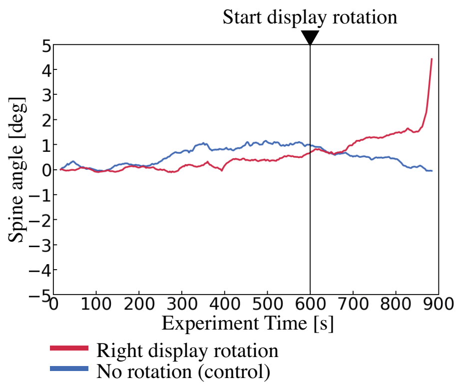

Figure 8: Right and left inclination of spine of right display rotation and no rotation conditions. Red line denotes right display rotation and blue line denotes no rotation.

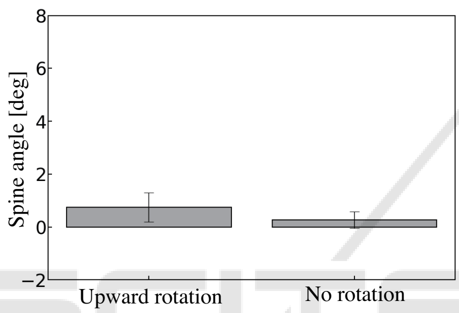

Figure 9: Displacement of the forward and backward inclination of the spine between last and first 10 seconds of display rotation.

and right is shown in Figure 7 and 8. In the right rotation condition, it can be seen that the angle of the spine is displaced in the positive x-axis direction (right) as compared with the control condition. On the other hand, it can be confirmed that in upward rotation condition, the y coordinate did not change despite the display's rotation.

In order to measure the angle displacement due to display rotation, the displacement between the angle for 10 s before the end of the display's rotation and the head coordinates for 10 s before the start of the display's rotation was regarded as the angle of the spine due to the display rotation. The displacements were calculated for each conditions for all participants and their mean and standard errors were calculated (Figure 9 and 10).

3.3 Discussion

Figure 9 shows that there is no large difference in the displacement of the forward and backward inclination of the spine between the upward rotation condition and the control condition. On the other hand, it can

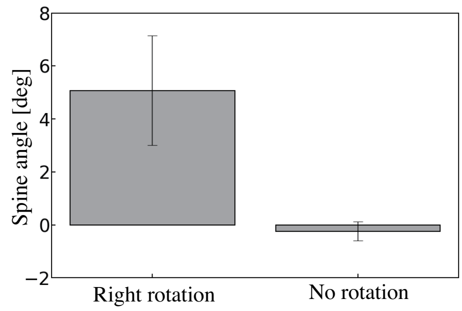

Figure 10: Displacement of the right and left inclination of the spine between last and first 10 seconds of display rotation.

be seen from Figure 10 that the displacement of the angle of the spine in the right direction was larger in the right rotation condition than in control condition, indicating that the head moved to the right. As the participant's head moved to the right due to the rotation of the display, it indicated that the rotating display has a potential to induce the worker's spine angle in a lateral rotation.

Then, we discussed the reason why upward angle displacement did not occur with upward display rotation. The Tetris task was to pile blocks falling from the top. It was considered that for participants, the visibility of the display did not get worse in the upward rotation condition compared to right rotation condition in the case of the vertical rotation. That's why participants did not look at the screen from above in order to improve it. In actual desk work, information such as web pages and documents are displayed from top to bottom. Therefore, even in actual desk work, there is a high possibility that head position adjustment is not possible by the vertical rotation of a display.

From the questionnaire and task performance, there was no large difference in task interference among all conditions. Therefore, there seemed to be no task interference by the rotation of the display.

Thus, there is a possibility of inducing the spine angle displacement with lateral rotation of the display without interfering with task. In the next chapter, on the lateral rotation in which the angle of the spine change was indicated, it was verified whether the angle of the spine can be induced only by the horizontal rotation of content in a display with a fixed orientation.

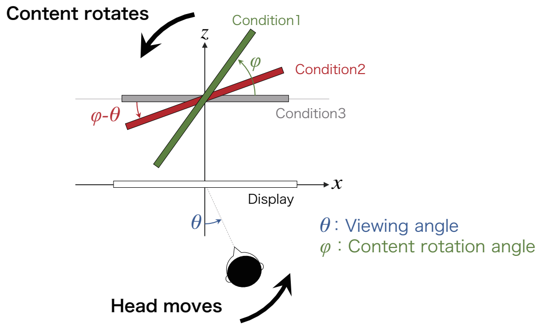

Figure 11: A vertical view of the display and participants. Red content indicates the content in condition 1 (right rotation without head-sync). Green content indicates the content in condition 2 (right rotation with head-sync). Gray content indicates the content in condition 3 (no rotation).

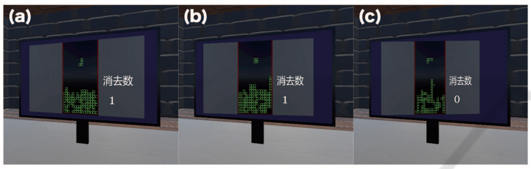

Figure 12: These are the displays seen by the participants when $\theta = 15$ *deg*. (a) no rotation condition. (b) right rotation with head-sync condition when $\phi = 30$ *deg*. (c) right rotation without head-sync when $\phi = 30$ *deg*.

4 USER STUDY 2

In study 1, we verified the possibility of lateral posture induction by physically rotating the display. This study verified whether posture can also be changed by the rotation of the content in the display.

This study was also conducted with participants with a within-subjects design. Participants were asked to solve a task located in the display. While participants solved the task, the content in the display was rotated to the right. This verified whether the angle of the spine of participants was induced to adjust in the direction of content rotation. There were three experimental conditions. Right rotation with synchronization of the head position, without synchronization, and no rotation. The head position of participants was measured to calculate the angle of the spine. Task results were measured as the task interfere level. These were compared among the conditions. The number of participants was 18.

4.1 Experiment Design

The experimental environment and flow of the experiment were almost the same as study 1. The experimental environment was created using VR and participants attached HMD. The difference was that the size of the displayed content was 80% as large as study 1. This is because if the size is the same as study 1, content is hidden because of the rotation.The task was Tetris in the same way as study 1.

There were three experimental conditions.

1. Right rotation without synchronization with the position of the head (right rotation with head-sync)
2. Right rotation with synchronization with the position of the head (right rotation without head-sync)
3. No rotation.

Similar to study1, the negative rotation of the y-axis (left rotation) was excluded from the conditions considering the symmetry. The order of the conditions was counterbalanced.

A vertical view of the display and content rotation is shown in Figure 11. In condition 1, content (green content in Figure11) was rotated at 0.3 deg/s like study 1. The maximum rotational angle was 30 deg. We defined the rotational angle of content in condition 1 as ϕ. In condition 2, if participants moved their head with the content's rotation, the visibility of the content was improved. The angle between the z-axis (forward) and the viewing direction of a participant is defined as θ (viewing angle) θ was calculated from the head position of the participants (x, z). Using these, the rotation angle of content in the display was presented in $\phi - \theta$ (red content in Figure11). For example, if a head was always perpendicular to the content, the rotation angle of a content is always 0 deg. Task seen by the participants is shown in Figure 12.

The method of measuring the angle of the spine and the task performance of participants was also the same as study 1.

4.2 Result

An example of the angle of the spine of a participant in every condition is shown in Figure 13 and 14. It can be seen that in right rotation with head-sync condition, the angle of the spine changed in the positive x-axis direction (Right) compared with no rotation condition.

The results of all 18 participants is shown. The displacements of the angle of the spine were calculated for all participants and the mean and standard errors of these displacements were calculated. A comparison of the displacement in all three conditions is shown in Figure 15.

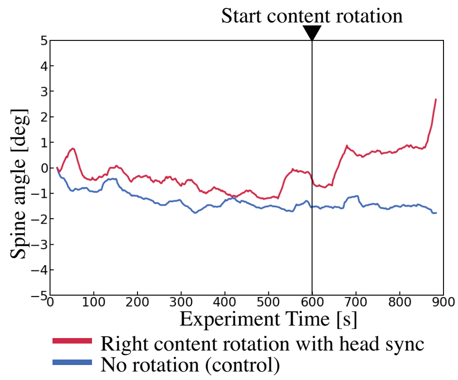

Figure 13: Right and left inclination of spine with right content rotation with head sync and no rotation conditions. Red line denotes right content rotation with head sync and blue line denotes no rotation.

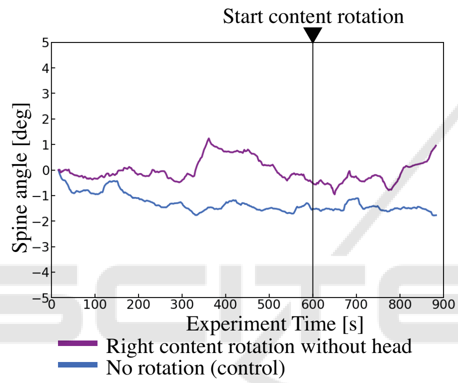

Figure 14: Right and left inclination of spine of right content rotation without head sync and no rotation conditions. Purple line denotes right content rotation without head sync and blue line denotes no rotation.

4.3 Discussion

It can be seen that the head position significantly adjusted in the positive x-axis direction (Right) in both the right rotation with and without head-sync conditions. Based on this, there is an indication of the possibility of inducing the angle of the spine by the rotation of the content. There was no significant difference in induced head displacement in rotation with or without head-sync. The displacement of the angle was smaller than that of physical display rotation in study1.

Next, the reason why there was no difference between the displacement of the angle with and without head-sync is discussed. In this study, $\phi - \theta$ is almost same as ϕ because head displacement is no more than 10 mm. Accordingly, it was considered that there was no difference in the displacement of head regardless of the synchronization of the rotation with head.

The displacement of the angle of the spine in this

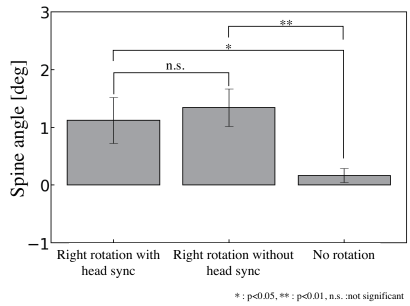

Figure 15: Displacement of the right and left inclination of the spine between the last and first 10 seconds of display rotation.

study was smaller than the physical display rotation in study 1. This is thought to be because participants were not motivated to look at the display. The visibility of the content was not improved because if participants displaced their head and looked at the display.

From the questionnaire and task performance, there were no large difference in task interference among all conditions. Therefore, there seems to be no task interference by rotating the display.

In study 1, by rotating the display laterally, the possibility of inducing the head to adjust laterally without interfering task performance was indicated. In study 2, by rotating content in a display laterally, the possibility of inducing the head to adjust laterally without interfering task performance was also indicated. In addition, it was suggested that the head induction did not depend on whether the rotation synchronized with head position.

5 CONCLUSION

In this paper, we proposed content rotation as means of indirect posture correction without large-scale equipment. This is a method that rotated content in the opposite direction of the direction of head movement. We expected that users would unconsciously move their head to look at the content.

To realize the proposed method, we conducted two user studies. First, we verified whether the head followed the display rotation. As a result, the direction of the spine tilted to the right at an average of 5 deg against display right rotation. However, the spine did not tilt against display upward rotation. Second, we verified whether the angle of the spine also followed the content's right rotation. As a result, the direction of the spine tilted to the right at an average 1 deg against content right rotation. Therefore, we showed the possibility of inducing the spine to the left and right directions by rotating the content shown in the display.

In this study, we could not induce the spine to tilt in the upward direction. Future studies may investigate the cause. In addition, we did not verify whether content rotation can induce the improvement of poor posture to good posture. Furthermore, we need to develop a system that can be embedded to the office environment.

We expect that our proposed method will promote the low-cost prevention of musculoskeletal disorders in office workers.

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