Crimson Tendons: Designing a Mouse Usage Visualization System to Prevent Mouse Overuse Behaviors

Tiantian Zhao, Anna Sui, Jiale Shi, Ting Hu, Xiaoyu Zhang, and Xipei Ren(✉)

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

Abstract. Overuse of the mouse is one of the possible behaviors that trigger carpal tunnel syndrome (CTS). In this study, we designed Crimson Tendons, a mouse use behavior visualization system. The system consists of a physical visualization device and a data canvas that records mouse usage data. The physical device uses flowing red liquid to map the mouse usage state. We proposed a preliminary user test and performed qualitative and quantitative analyses. The experimental results indicated that the device was attractive to users. They would choose to take active breaks to watch the flowing effect of the device, and this feedback would help us iterate on the design concept. The system has a novel design and contributes to the promotion of office health by helping to improve people's work habits and reduce the risk of CTS and other related diseases.

Keywords: Mouse Use · Interaction Devices · Visualization · Office Health

1 Introduction

Carpal tunnel syndrome (CTS) is one of the most common musculoskeletal disorders and technical disorders [1, 2]. The main symptoms of CTS are pain, numbness, a cold sensation, and paresthesia. The effectiveness of pharmacological and surgical treatments for CTS remains controversial [3, 4], so prevention and timely intervention are particularly important to reduce the prevalence of CTS. Studies have shown that computer work and prolonged operation of a computer mouse are associated with an increased risk of carpal tunnel pressure, and that tingling and numbness in the right hand are associated with time spent using the mouse device [5, 6]. Therefore, mouse use behavioral interventions for students and office workers working with highly exposed computers are essential to reducing the prevalence of CTS in this group.

Various interventions have been suggested by previous studies to prevent or alleviate CTS, with a primary emphasis on ergonomic factors [3], including the use of vertical mice and wrist supports. However, there is insufficient evidence to confirm their effectiveness [7]. In addition, studies have shown that rest may be used as activation or recovery time, so increasing rest time could aid in preventing CTS [8, 9].

P. Ciancarini et al. (Eds.): ICEC 2023, LNCS 14455, pp. 507–517, 2023.
https://doi.org/10.1007/978-981-99-8248-6_48

In summary, this paper proposes Crimson Tendons, a system to visualize mouse usage behavior. The system consists of a physical device and a data visualization canvas. The users can interact with the device while using the mouse. We hope that the visualization system will provide visual impact and intuitive data to draw users' attention and trigger their reflection, thus increasing the rest time during mouse use, preventing the occurrence of diseases like CTS, and promoting office health.

2 The Presentation of Data

2.1 Visualization Strategy

Considering the usage scenario of the users, the main visualization strategy of Crimson Tendons is to encourage users to take active breaks through visual feedback. Therefore, we created a more appealing physical device inspired by the microscopic blood vessels of the hand. We focus on physical visualization since other windows often block the canvas, and physical devices provide an immersive experience that cannot be replaced by an interface. We also added a data visualization canvas to complement the physical device, enabling users to intuitively monitor their mouse usage data and use it as a basis for health analysis (see Fig. 1). Compared to the physical device, the canvas uses a simple and intuitive data presentation.

Fig. 1. Crimson Tendons system usage scenario.

2.2 Canvas Data Visualization

The data canvas records and visually presents mouse usage data. It was created using processing (see Fig. 2). Considering the influence of the touch panel and other factors, we take the cursor state instead of the mouse use state and call Java's Robot class in

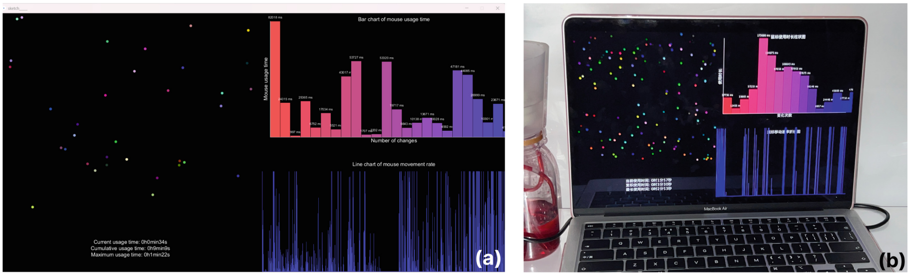

Fig. 2. Crimson Tendons' visual data canvas: (a) overall usage interface; (b) real-world usage scenario.

processing to monitor the cursor's position and movement state on the whole screen, so as to calculate the mouse's use length and movement rate.

The canvas consists of three parts: recording the user's current mouse usage time, segmented usage time, and mouse movement rate in the form of polka dots, bars, and lines, respectively (see Table 1). The reason for the inclusion of mouse movement rate is that dragging tasks also have a significant effect on wrist pressure [10]. Considering that users may pause their mouse movement while reading pages or performing other tasks on the computer, we used the criterion of whether the cursor position remains unchanged for 60 s; if yes, this period of mouse use continues to be timed; if not, this period pauses until the next time the cursor moves to start a new period.

Table 1. Data visualization interface related data indicators and their interpretation.

Data indicators	Specific explanation
Number of wave points	Number of wave points (pcs) = current usage time (sec)
Current usage time	Current usage time is the usage time of the current number of changes
Cumulative usage time	Cumulative usage time is the sum of the current usage time for all changes, also called total mouse usage time
Maximum usage time	Maximum usage time is the maximum of the current usage time
Mouse segmentation usage time	Mouse segmentation usage time is the data set of the current usage time
Number of changes	Every continuous pause up to 60s is a change
Mouse movement rate	The mouse movement rate is the data set of the single mouse movement rate

2.3 Physical Visualization

Crimson Tendons' physical interaction device is visualized in the form of a liquid flow mapping the state of mouse use. We crafted the main body of the hand prototype using lightweight white clay and wrapped transparent tubing around it, and then connected it to the water reservoir and the circuitry (see Fig. 3). The system's interactivity is achieved through an Arduino UNO board, a relay module, a self-priming pump, batteries, and the program in Processing. Specifically, when users use the mouse, Processing monitors the cursor's movement and communicates with Arduino in a serial port, transmitting the cursor's state as digital signals to the relay module, thus controlling the pump's on-off switch. When the mouse is in use, the liquid in the device flows, and only when the mouse is out of use for a period of 3 s does the relay stop working and the liquid in the device becomes stationary.

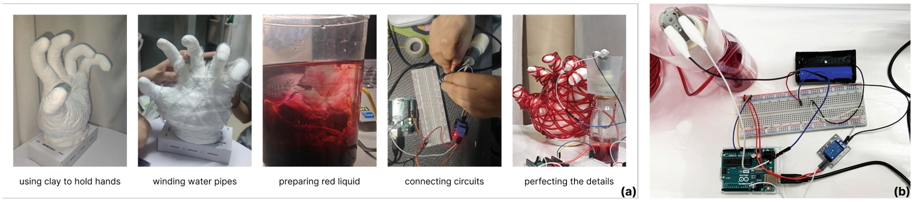

Fig. 3. Realization of the physical device: (a) prototyping process for physical device; (b) circuit realization.

Regarding the presentation effect of this device (see Fig. 4), we controlled the water level in the reservoir to allow a certain amount of air to enter the pipe, ensuring a clear flow effect. The twisted pipe mimics hand blood vessels, with red liquid inside symbolizing blood flow, creating a distinct contrast against the white hand-shaped body, making users facilitate their association with their hand's health status, prompting self-reflection, and serving as a reminder. In terms of the interaction experience, the flowing liquid provides real-time visual feedback, accompanied by subtle water flow sounds, contributing to alleviating workplace stress.

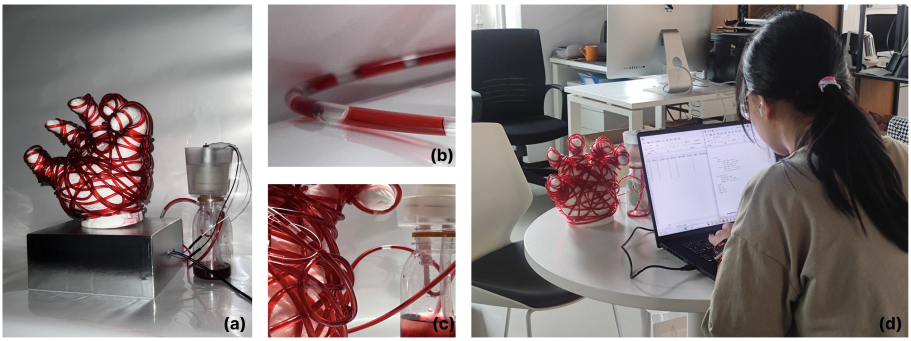

Fig. 4. Crimson Tendons' physical device: (a) overall part; (b) water pipe; (c) reservoir; (d) real use scenario.

3 User Test

3.1 Experiment Walkthrough

Participants. Three subjects were recruited for the experiment walkthrough. All of them were graduate students in design, so we could get some professional feedback. We numbered the participants as P1, P2, and P3.

Setup and Procedure. The subjects were first required to experience the data canvas under the guidance of the researchers and then watch a video of the process of using the physical device (see Fig. 5). After watching the video, we conducted semi-structured interviews (see Table 2).

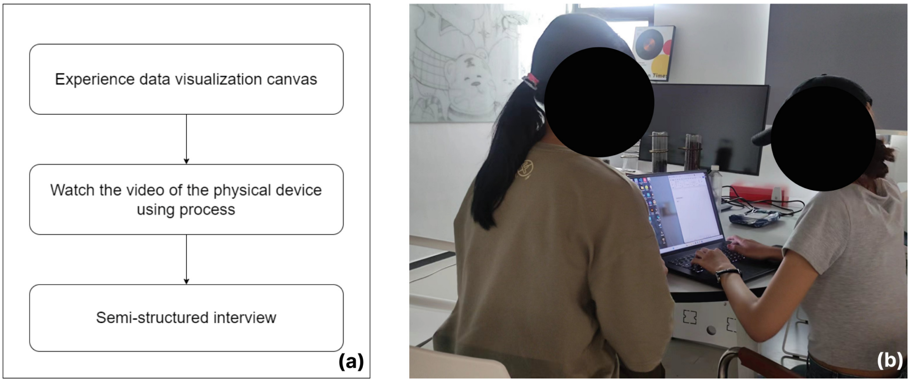

Fig. 5. Process of experiment walkthrough: (a) experimental flow chart; (b) interview process.

Table 2. Semi-structured interview question categories and interview directions.

Question category	Interview direction
Basic personal information	Gender, age, occupation, etc
The use of the mouse	Use of equipment, habits, frequency of symptoms of CTS, etc
Data canvas experience	Experience, impact on behavior, willingness to use, etc
Physical device experience	Feelings of using (watching videos), willingness to use, influence on behavior, linkage with interface, etc
Suggestions for the system	Suggestions for presentation, data types, user experience, etc

Data Collection. The data we collected was mainly from the semi-structured interviews. When subjects were interviewed, the main questions focused on their experience and feedback. During the interview process, we recorded the whole process in audio, and after the interview, we transformed it for organizing and coding analysis.

3.2 Pilot Study

Participants. Three subjects were recruited for a pilot study, all of whom were heavy mouse users with a fixed office location and graduate students in design. We numbered the participants as P4, P5, and P6.

Setup and Procedure. We assumed that during the pilot study mouse use time and movement rate decreased and the frequency of breaks increased when the user used the physical device. Unlike the walkthrough experiment, users actually used the physical device and the data canvas. The experiment was set up as a within-subjects experiment because we wanted to minimize the effect of individual differences.

The experiment was divided into two phases (see Fig. 6): in Phase 1, the subjects only used the data canvas to display data in real time and record data, and in Phase 2, the computer connected to the physical device while using the data canvas. The experimental time for both phases was 30 min, and the subjects used their computers for normal office work. The process of connecting the subjects' computers to the physical device and displaying the canvas was done under the guidance of the researchers. At the end of Phase 2, we conducted semi-structured interviews with users.

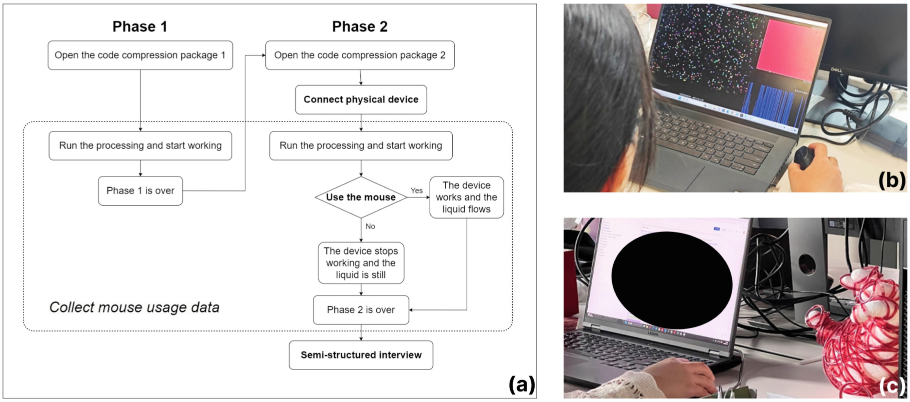

Fig. 6. Process of pilot study: (a) experimental flow chart; (b) Phase 1 experimental process; (c) Phase 2 experimental process.

Data Collection. Two types of data were collected. The data for quantitative analysis was collected through the program in processing, the data from user phases 1 and 2 will be calculated and analyzed in comparison. The data for qualitative analysis was collected through the user interview, which focused on the users' real feelings and suggestions for the system, and the rest was the same as the experiment walkthrough.

4 Results

4.1 Quantitative Findings from Pilot Study

Through the pilot study, we collected 30 min of mouse use data for each of the three subjects before and after using the physical device (see Table 3), and the length of mouse use was greater in Phase 2 than in Phase 1 for all of the subjects (see Fig. 7(a)), which is contrary to our hypothesis. P6 did not take a break in Phase 2 (see Fig. 7(c)). Subjects' Phase 2 mouse movement rate means were all smaller than Phase 1 (see Fig. 7(b)), which is consistent with our hypothesis.

Table 3. Mouse use data of subjects in Phase 1 and Phase 2 during 30 min.

	Mouse segmentation usage time (unit: minutes)		Total mouse usage time (unit: minutes)		Mean value of mouse movement rate		Peak value of mouse movement rate	
	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
P4	0.16	3.89	13.19	**20.63**	34.99	**25.98**	1643.35	892.11
P5	4.03	10.71	15.56	**19.34**	60.74	**32.17**	1588.95	2175.83
	6.79	6.80						
	3.32	1.75						
	1.41	0.01						
		0.08						
P6	0.23	**24.01**	21.17	**24.01**	69.34	**38.35**	1701.17	1227.83
	1.50							
	9.14							
	2.09							
	3.40							
	1.67							
	3.14							

4.2 Qualitative Findings

In the user interviews for the walkthrough experiment and the pilot study, we obtained basic information about mouse usage habits and some feedback about the product from the subjects. All six subjects used the mouse more frequently and generally for studying, and their recent usage lengths reached more than 8 h, making them heavy users of the mouse with short rest periods during continuous use of the mouse. All six subjects in the user test had a high frequency of mouse use, with recent usage lengths of 8 h or more, were heavy users of the mouse, and had short breaks during continuous mouse use.

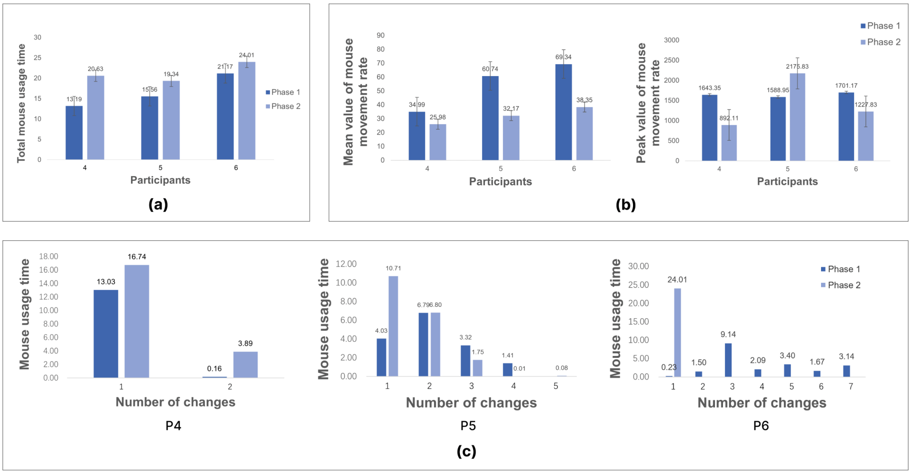

Fig. 7. Data of pilot study: (a) total mouse usage time (unit: minutes); (b) mean value and peak value of mouse movement rate data; (c) mouse segmentation usage time data for P4, P5 and P6 (unit: minutes).

The data collected through semi-structured interviews in both the walkthrough experiment and the pilot study was coded (see Table 4). Users of the data canvas mainly pay attention to the mouse usage time data, and most users express a willingness to record their own data to remind themselves regularly. Some users said they would like to clear the screen of the wave point and rest. For physical devices, some users feel afraid and think of their hands, which causes them to reflect. Additionally, some people find the devices intriguing, which could potentially divert their attention and disrupt their work. Users are interested in physical devices. P6 used the mouse consistently to observe the liquid flow, which may account for her lack of rest in Phase 2. Moreover, the participants provided suggestions to improve the system, requesting that the physical device be more connected to the data canvas. They also expressed a desire for interventions and long-term feedback.

Table 4. Users experience and feedback on data canvas, physical device and the whole system.

Categories	Experience and feedback	Examples
Visual canvas	Canvas attention	**"…paid more attention total time." (P1, P2, P3, P4, P5, P6)**
	Behavior influence	"…concentrate on not loafing on a job." (P5), "…deliberately stop when I see point." (P6) and "…take a look as a relaxation." (P4)

(*continued*)

Table 4. (*continued*)

Categories	Experience and feedback	Examples
	Intention to use	"…give me a general understanding of my work status." (P1), "…not limited to the computer screen." (P3)
Physical device	Physical device attention	"…the device attracts me more than the interface." (P1, P2, P3, P4, P5, P6)
	Reflection of the device	"amazing" (P6), "very artistic" (P1), "too concrete" (P3), "a little scary" (P4), "life is passing" (P2), "let me divert attention, will make me afraid" (P5)
	Behavioral influence	**"it reminds me of my own hands." (P2, P5), "it will make me want to see." (P1, P6)**, "…ignore it after I get into work." (P3)
	Intention to use	**"…help people decompress or relieve their mood." (P2), "it can make the harm more serious and cause more reflection." (P2, P5)**
The whole system	User experience	"…very creative…" (P4), "water flows when the mouse is stationary, and it will be better to explain that water is stationary when it is used." (P5)
	Improvement suggestions	"…change the water flow rate according to the number of clicks." (P4), "on the screen, the flowing state echoes in color." (P3)

5 Discussion

Firstly, this paper proposes a physical visualization for mouse usage data. By quantitative analysis, we find that the subjects' mouse movement rate means in Phase 2 is lower than in Phase 1, which indicates that the physical device has a certain intervention on the user's mouse movement rate. As previous studies have shown that the wrist movement speed is smaller under pressure conditions [11], and the use of water sounds has a good effect on the users' psychological healing [12, 13], the sound of water in the physical device may have a certain effect on the user's stress relief. In addition, a part of the quantitative analysis results did not conform to the hypothesis, after adding the physical device, the total mouse use time was more than that in Phase 1, and the number of breaks was less, which was contrary to the hypothesis. One of the reasons for this may be due to the fact that we only designed a pilot study with a shorter and fewer number of subjects, and some chance occurred. Another reason could be that the subjects were more interested in the flow state of the device and thus appeared to use the mouse. Based on this result, we conjecture that it may be more beneficial to change the mouse state corresponding to the physical device state in order to make the user take a break to look at the flow state.

The effectiveness of the system is difficult to account for statistically due to the limited number of participants in the current user test. In the future, we will expand the scope of the experiment and validate the method's effectiveness in conjunction with further iterations of the prototype.

Secondly, during the user test, semi-structured interviews were conducted with participants from both the experiment walkthrough and the pilot study. Through qualitative analysis, the feedback provided by the users was collected on the system and mouse usage related health. Participants were found to pay more attention to the physical device than to the canvas. The reason for this observation may be that the physical visualization is more effective in visualizing the state of mouse usage while the user is working compared to the canvas. The majority of the existing research focuses on collecting mouse usage data with the aim of predicting health problems [14]. Additionally, a few studies concentrate on providing real-time user feedback to prevent health problems. As a result, this paper proposes an improved direction for visualizing mouse usage data, and possibly other types of health and behavioral data as well, by pairing physical with canvas visualization. Furthermore, users have provided feedback on the product system, and we plan to continue iterative optimization in future research.

6 Conclusion and Future Work

This paper describes Crimson Tendons, a mouse behavior visualization system, including the design and implementation of a liquid flow device to visualize the user's mouse behavior and an associated data visualization canvas. We also conducted a preliminary user test to verify its effectiveness. Mouse behavior is visualized through the red liquid flow in the device. Firstly, the device has an exaggerated but figurative shape, which directly reminds the user of the state of the hand when using the mouse and causes the user to reflect on the situation, thus preventing diseases such as CTS. At the same time, through the flow of water and the state of the mouse, the mapping relationship shifts the user's attention and soothes the user's stress and emotions. Secondly, the data canvas displays and records mouse usage data in real time, allowing the user to track long-term mouse usage behavior and providing a data record of their own office health behavior. We obtained valuable user feedback through user test, and in future research, we will iterate based on the test results and conduct large-scale and longer-term user tests with the updated and iterated system for a new round of product iteration.

Acknowledgements. Thanks to the participants in this study. This work is supported by The National Social Science Fund of China (21CG192) and Ministry of Education of China's First Batch of New Humanities Research and Reform Practice Project (2021160005).

References

1. Da Costa, J.T., Baptista, J.S., Vaz, M.: Incidence and prevalence of upper-limb work related musculoskeletal disorders: a systematic review. Work **51**(4), 635–644 (2015)
2. Tiric-Campara, M., et al.: Occupational overuse syndrome (technological diseases): carpal tunnel syndrome, a mouse shoulder, cervical pain syndrome. Acta Informatica Medica **22**(5), 333 (2014)
3. Schmid, A.B., Kubler, P.A., Johnston, V., Coppieters, M.W.: A vertical mouse and ergonomic mouse pads alter wrist position but do not reduce carpal tunnel pressure in patients with carpal tunnel syndrome. Appl. Ergon. **47**, 151–156 (2015)
4. Ali, K.M., Sathiyasekaran, B.W.C.: Computer professionals and carpal tunnel syndrome (CTS). Int. J. Occup. Saf. Ergon. **12**(3), 319–325 (2006)
5. Eleftheriou, A., Rachiotis, G., Varitimidis, S.E., Koutis, C., Malizos, K.N., Hadjichristodouloul, C.: Cumulative keyboard strokes: a possible risk factor for carpal tunnel syndrome. J. Occup. Med. Toxicol. **7**(1), 1–7 (2012)
6. Andersen, J.H., Thomsen, J.F., Overgaard, E., et al.: Computer use and carpal tunnel syndrome: a 1-year follow-up study. JAMA **289**(22), 2963–2969 (2003)
7. Trillos-Chacón, M.C., Castillo-M, J.A., Tolosa-Guzman, I., Medina, A.F.S., Ballesteros, S.M.: Strategies for the prevention of carpal tunnel syndrome in the workplace: a systematic review. Appl. Ergon. **93**, 103353 (2021)
8. Galinsky, T., Swanson, N., Sauter, S., Dunkin, R., Hurrell, J., Schleifer, L.: Supplementary breaks and stretching exercises for data entry operators: a follow-up field study. Am. J. Ind. Med. **50**(7), 519–527 (2007)
9. Charpe, N.A., Kaushik, V.: Reducing symptoms of carpal tunnel syndrome in software professionals. Stud. Ethno-Med. **6**(1), 63–66 (2012)
10. Keir, P.J., Bach, J.M., Rempel, D.: Effects of computer mouse design and task on carpal tunnel pressure. Ergonomics **42**(10), 1350–1360 (1999)
11. Wahlström, J., Hagberg, M., Johnson, P., Svensson, J., Rempel, D.: Influence of time pressure and verbal provocation on physiological and psychological reactions during work with a computer mouse. Eur. J. Appl. Physiol.ur. J. Appl. Physiol. **87**, 257–263 (2002)
12. 김진숙, 신원섭, 김명종. 치유의숲 소리, 경관, 소리경관 (soundscape) 에 따른 선호도 및 심리적 회복감 분석. 한국환경과학회지**30**(3), 267–277 (2021)
13. Song, I., Baek, K., Kim, C., Song, C. Effects of nature sounds on the attention and physiological and psychological relaxation. Urban Forestry Urban Green. **86** 127987 (2023)
14. Andersen, J.H., Harhoff, M., Grimstrup, S., et al.: Computer mouse use predicts acute pain but not prolonged or chronic pain in the neck and shoulder. Occup. Environ. Med. **65**(2), 126–131 (2008)