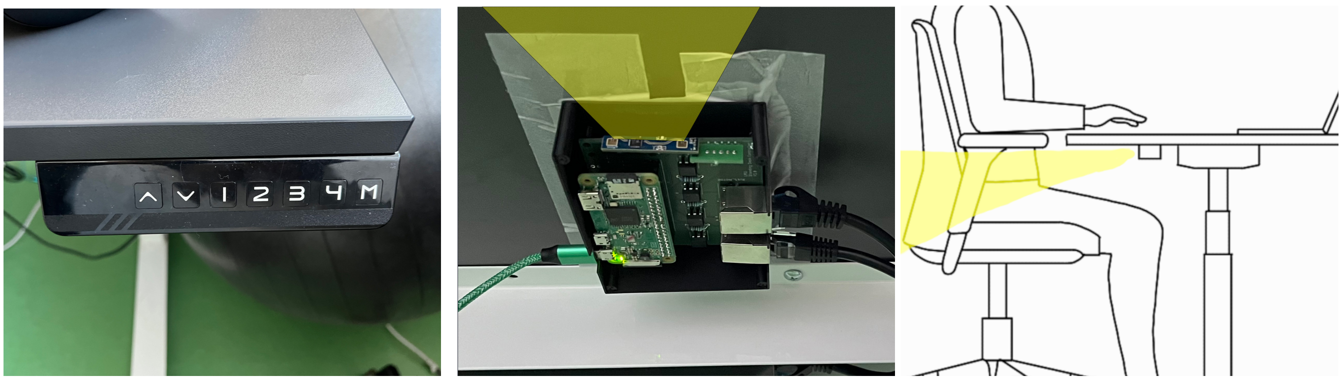
Standtroller: The Autonomous Standing Desk Controller

Luke Haliburton
LMU Munich
Munich, Germany
luke.haliburton@ifi.lmu.de

Teodora Mitrevska
LMU Munich
Munich, Germany
teodora.mitrevska@ifi.lmu.de

Johannes Kleine
LMU Munich
Munich, Germany
johannes_kleine@gmx.de

Sven Mayer
TU Dortmund University
Dortmund, Germany
Research Center Trustworthy Data Science and Security
Dortmund, Germany
sven.mayer@tu-dortmund.de



(a) Keypad **(b) Control Unit Setup** **(c) Detection Area**

Figure 1: Images of a typical keypad, the control Unit mounted to a desk, and a visualization of the detection area for the presence sensor.

Abstract

Modern knowledge workers conduct most of their work sitting at a desk. Consequently, offices are highly sedentary, which is correlated with increased risks of health complications. Standing desks, which enable users to periodically transition between sitting and standing, are one proposed solution, but users rarely adjust their desks in practice. In this paper, we present Standtroller, a retrofittable system that enables standing desks to move autonomously. We use a mmWave sensor to detect user presence and move the desk when the user is absent to avoid interruptions, and developed a desktop application to visualize standing time and allow users to adjust settings. We evaluated the system in a three-week within-subject field study (N=13) and found that moving during absences is accepted, but proactive feedback and simplified configuration could better support users. We contribute our open-source system and concrete design recommendations to pave the way for future smart workplace wellbeing systems.

This work is licensed under a Creative Commons Attribution 4.0 International License.

MuC '26, Duisburg, Germany

© 2026 Copyright held by the owner/author(s).

ACM ISBN 979-8-4007-2611-8/2026/08
https://doi.org/10.1145/3820253.3820274

CCS Concepts

• **Human-centered computing → Human computer interaction (HCI)**; *Empirical studies in HCI*; **Interactive systems and tools**.

Keywords

standing desk, smart furniture, healthy work, work environment, smart environment

ACM Reference Format:
Luke Haliburton, Teodora Mitrevska, Johannes Kleine, and Sven Mayer. 2026. Standtroller: The Autonomous Standing Desk Controller. In *Proceedings of Mensch und Computer 2026 (MuC '26), August 30-September 02, 2026, Duisburg, Germany*. ACM, New York, NY, USA, 15 pages. https://doi.org/10.1145/3820253.3820274

1 Introduction

Contemporary office environments are designed to maximize efficiency and productivity, often at the expense of any physical movement [31]. Consequently, knowledge workers remain sedentary for most of their work hours [15, 52]. Over the long term, inactivity is a significant public health concern [11], linked to increased likelihoods of cardiovascular disease [25], diabetes [65], chronic lower back pain [6], and overall higher mortality rates [55].

This highlights the importance of designing technologies that reshape workplaces by incorporating opportunities for movement and disrupting prolonged sedentary behavior. Electric sit-stand desks are one potential solution that enables users to work while standing [13] and encourage frequent posture shifts, which are beneficial to overall health [11, 23, 24]. However, despite a fundamental interest in reducing sedentary time and standing more [14], research shows that desk owners rarely use standing mode in practice [56, 64].

In response, researchers have investigated how to encourage users to stand more often. Sharma et al. [58] developed a system that measures desk height and prompts users to stand if they have not met their goals, finding that the number of desk position changes per workday doubled with reminders. Autonomously moving sit-stand desks can initiate posture changes by moving on their own. In a study by Kim et al. [41], participants showed mixed reactions toward an autonomous sit-stand desk that changed position at regular intervals. To investigate interruptions, Lee et al. [45] conducted a study in which participants used a seemingly autonomous moving desk while performing tasks. Their results show that the best moments for desk movements are when users transition between tasks, in line with other work on interruptions [35]. Haliburton et al. [30] developed a plug-and-play system for remotely controlling standing desks and explored user preferences for desk behavior through three modes of autonomy. Their "Smart Mode," which moves the desk when the user is absent from their computer, was the most accepted and contributed to increased standing time.

In this paper, we designed and implemented a standing desk control system, called Standtroller, that detects user presence and autonomously moves the desk in times of absence. Building upon the open-source controller by Haliburton et al. [30], we developed a new plug-and-play system with a millimeter wave (mmWave) presence sensor and implemented a cross-platform dashboard application that provides real-time control, statistics, and customizable settings. Our system more robustly captures user presence in a range of office situations and enables users to control and personalize their autonomous standing desk experience. We evaluated our system in a three-week within-subject field study to understand how users interact with the system in their real workplaces, aiming to address the following research question:

RQ: *How can a non-interrupting autonomous standing desk support users in reaching their desired amount of standing time?*

Our results show that participants stood significantly more using the Standtroller compared to a manually controlled desk. Interview responses from participants revealed that moving the desk in their absence was accepted and rated as useful. The autonomous transitions also reminded participants that standing at their desks was a possibility and inspired them to develop working-while-standing routines. The results also suggest that standing data and achievements should be communicated more actively and desk configuration should be simplified and tailored to user behavior. Overall, we contribute i) an open-source autonomous standing desk system, incorporating a presence sensor to facilitate non-interrupting height transitions, ii) a personal informatics tool to track standing time at work in the form of a cross-platform desktop application, and iii) concrete design recommendations to guide future designers of workplace technologies aimed at promoting physical activity.

2 Related Work

In the following, we introduce sedentary behavior in the workplace and associated Human Computer Interaction (HCI) literature aiming to increase workplace physical activity. We then review work on self-tracking, and provide an overview on smart furniture and autonomous standing desks.

2.1 Sedentary Workplaces

Knowledge workers experience chronic sedentary conditions through prolonged periods of sitting [15–17, 62]. The negative health implications of sedentary behavior are numerous, with consequences for diabetes [65], chronic pain [6], cardiovascular health [25], and overall mortality [55]. Although these risks are well-known, knowledge workers spend between two-thirds [15] and nearly 90% [52] of their working time sitting.

Frequent posture changes are a common recommendation to mitigate health risks associated with prolonged sitting. For instance, the 20/8/2 rule proposed by Kar and Hedge [38] (20 minutes sitting, 8 minutes standing, and 2 minutes moving per half hour) suggests that alternating between sitting and standing positively impacts health. Further research by Diaz et al. [23] indicates that life expectancy increases when individuals move every 30 minutes. Some investigations have attempted to introduce shifts in physical activity to the workplace through breaks [12, 44, 47], although these often reduce productive time. Past work has also investigated "microbreaks," which improve wellbeing without decreasing productivity. Overall, a scoping review [18] found that only a few investigations propose integrating physical activity into productive activities, while most focus on prompting breaks.

In contrast, several approaches in HCI directly incorporate physical activity into productive work by promoting active ways of working. For example, there is a body of work on technology-supported walking meetings. Researchers have developed sets of challenges and opportunities for designing walking meeting technologies [21, 32] and created prototypes for recording [29], infrastructure-based note-taking [20], or persuading [2–4]. Our work is aligned with the infrastructure approach by Damen et al. [20], which incorporates activity-promoting solutions directly into the work environment.

2.2 Self-Tracking and Reflection

Several studies have shown that visualizing sitting time, step count, or screen time can motivate users to engage in physical activity. Fortmann et al. [26] developed an ambient light that uses color changes to visualize health data, and found that it increased daily steps and movement frequency. Mateevitsi et al. [49] used a similar approach, with a motion sensor and color visualization to alert users about prolonged sitting. Similar approaches can be found in other literature that activates a display when a person has been sitting for too long [51], or visualizes computer activity to promote physical activity [9], or using embedded visualizations by growing ivy on an office chair [50]. These approaches have shown promise by increasing awareness, promoting self-reflection, and increasing physical activity. While the aforementioned approaches promote physical movement in general, Sharma et al. [58] investigated how software that visualizes personal standing desk usage can influence the frequency of position changes. In their two-month study, participants were reminded of their physical activity through software notifications and personal statistics, which doubled the daily number of desk transitions. This aligns with other studies confirming that self-tracking and goal-setting can promote physical activity [53, 54]. Inspired by this, and other work in personal informatics, we incorporate goal-setting and personal statistics visualizations into our prototype to encourage reflection and motivation.

2.3 Smart Office Furniture for Behavior Change

Researchers have proposed several approaches to incorporate behavior change in workplaces by adding automated behaviors to office furniture [16]. Automatic office furniture has been employed as an intervention in the workplace to encourage behavior change [16]. Kronenberg and Kuflik [43] proposed a system that monitors the user's posture and automatically adjusts the position, height, and orientation of a computer screen for better alignment. Fujita et al. [27] designed an office chair that subtly tilts the seat to encourage posture change. They show that the autonomous movement did not affect objective task performance, but speed influenced user acceptance.

A literature review by Zhu et al. [67] highlights that treadmill desks and other workplace-integrated physical interventions can effectively reduce sedentary time and promote movement. Studies suggest that standing desks, under-desk cycling setups, and treadmill desks can help decrease workplace inactivity while improving mood and reducing stress [28, 48], all without compromising productivity [39]. Additionally, moderate-intensity exercise on a cycling workstation during simulated office tasks has been found to increase physical activity without raising error rates, though it does lead to longer task completion times [42]. In a more passive approach, Damen et al. [19] developed furniture called "PositionPeak" that establishes a meeting room environment in which users are encouraged to move and avoid sedentary behavior. They found that users moved more often and had effective meetings, but were also inconvenienced. In a similar approach, Damen et al. [22] designed an "Office Jungle" that fosters movement and active ways of working.

Researchers have also designed automated furniture to enhance convenience. Sirkin et al. [60] developed a robotic footstool that autonomously moves toward seated users, encouraging them to place their feet on it. Research on adaptable furniture has explored designs that alter their shape and function to accommodate various needs. For instance, Takashima et al. [61] introduced a transformable and interactive digital desk capable of shifting between circular, square, and rectangular forms. This desk also features a display that dynamically adjusts its shape in sync with the table's transformations.

2.4 Autonomous Standing Desks

As the primary work location for many office workers, desks are a prime candidate for automation. Electronic sit-stand desks are adaptable pieces of office furniture that enable users to perform work tasks in sitting or standing positions. Standing desks have been shown to effectively lower discomfort [13]. There are several smart standing desks available on the market. For example, the "Autonomous SmartDesk Connect" and the "Lander Desk" by iMovR both use notifications to remind users to stand up. The "AiT SmartOne" offers similar functions and monitors air quality. The "Stir Kinetic Desk" uses tactile feedback to remind users to change their standing position. Lastly, "Nextergo", which tracks sitting and standing times, allows users to set activity goals and provides instructions for fitness exercises. Many of these desks are "smart" in the sense that they collect user data and can be programmed for specific behaviors.

While standing desks are increasing in popularity commercially, there have been limited investigations into how they should behave. Kim et al. [41] investigated a desk that automatically changes positions at regular, predetermined intervals. They found that about half the users were satisfied with a regularly shifting desk, while the remainder preferred to maintain manual control. In a similar study by Lee et al. [45], participants performed tasks such as typing, cutting, and reading to investigate opportune moments for desk movement. Their results indicate that the moment of switching from one task to another is the best time for an autonomous height adjustment. The investigation by [30] is most closely related to our work. They developed a plug-and-play system to remotely control standing desks and investigated how users want their desks to behave. They implemented three modes: Interval, where the desk moves up once per hour; Adaptive, where the desk moves up once per hour, but only if it was not already in a standing position within the last hour; and Smart, where the desk only moves up when the user has been away from their workspace for at least 3 minutes. All autonomous modes increased standing time, but the Smart Mode was most accepted because it avoided interruptions. However, their system only captured computer activity, so it still interrupted users occasionally. In our work, we build off of Haliburton et al. [30] by incorporating their findings about interruptions and their concept of a plug-and-play system. We take this work further by detecting user presence regardless of task, and create a desktop application for users to view their statistics and have direct control over the desk behaviors.

3 Design & Implementation of Standtroller

This section outlines the design and implementation of the hardware, firmware, and front- and back-end software of Standtroller.

3.1 Design Goals

Our aim was to develop a standing desk controller that can be easily retrofitted to existing standing desks with minimal installation effort. We used the work by Haliburton et al. [30] as a basis upon which to build our system and added additional design goals to address certain limitations in their work. In particular, we aimed for our controller to be able to sense when a user is present at their desk in a privacy-preserving manner regardless of their computer activity. Additionally, we wanted users to be able to adjust the autonomous behavior of their desks so that they feel in control. We also wanted to display standing statistics to users for personal informatics and motivation purposes. Finally, we aimed to establish near real-time communication between the controller and the back end to accurately time desk transitions and refresh data on the display dashboard. See Table 1 for a summary of the design goals and implementations.

Table 1: A summary of the design goals and associated implementations.

Design Goal	Description	Implementation
Retrofittable	The controller should be easy to install on existing standing desks	Similar to [30], the prototype is installed by plugging it in between the keypad and the motor module with 8P8C cables.
Detect User Presence	The system should detect when users are present at their desks regardless of the computer activity	We use a mmWave presence sensor which captures the presence of a person (or any slightly moving object) even if the person is sitting relatively still.
Privacy Preserving	The user detection system should preserve the privacy and identity of the user.	The mmWave sensor sends a binary signal to our system indicating only if a moving object is present.
User Adjustable	Users should be able to adjust the behavior of their own desk and define their own triggers for sitting and standing.	We implemented a desktop application where users can adjust numerous settings, enabling them to define the conditions under which the desk will move.
Personal Informatics	For self-reflection and motivation, users should be able to view statistics about their own standing behaviors.	We implemented a desktop application where users can see their standing and sitting times and their goals on a daily and weekly basis.
Near Real-time	The system should communicate in near real-time to enable accurate tracking and desk transitions and direct control of the desk from the desktop application.	We use Websockets for communication and built our system on a Raspberry Pi with Python (upgraded from MicroPython on an Arduino compared to [30]).

3.2 Control Unit

The control unit, depicted in Figure 2, is comprised of three main components: an electric circuit with optocouplers and resistors for reading and creating desk signals, a mmWave presence detector, and a Raspberry Pi for computing.

3.2.1 Reading and Creating Desk Signals. The seven-button keypad, shown in Figure 1a, typical of the standing desk models that we used for our implementation consists of two arrows for moving up and down, four digits for preset heights, and one modification key for assigning presets. Each key pressed on the keypad transmits a specific signal to the desk motor module, which interprets the signals and either moves the desk up or down. Haliburton et al. [30] found that signals are transmitted using an 8P8C cable containing eight wires (e.g., LAN cable). For each signal, certain combinations of wires are activated. For instance, pressing preset button 1 on the keypad activates wire 7 and 8, while preset 2 only activates wire 6. We used this knowledge to read signals from the wires and send custom signals by simulating keypad presses. We used two 8P8C connectors, shown in Figure 2, to redirect the signals to our custom circuit board, and used optocouplers to enable manual key presses to pass through to the motor module.

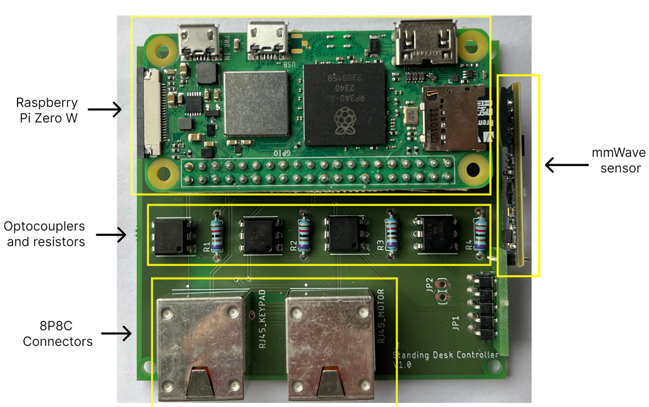


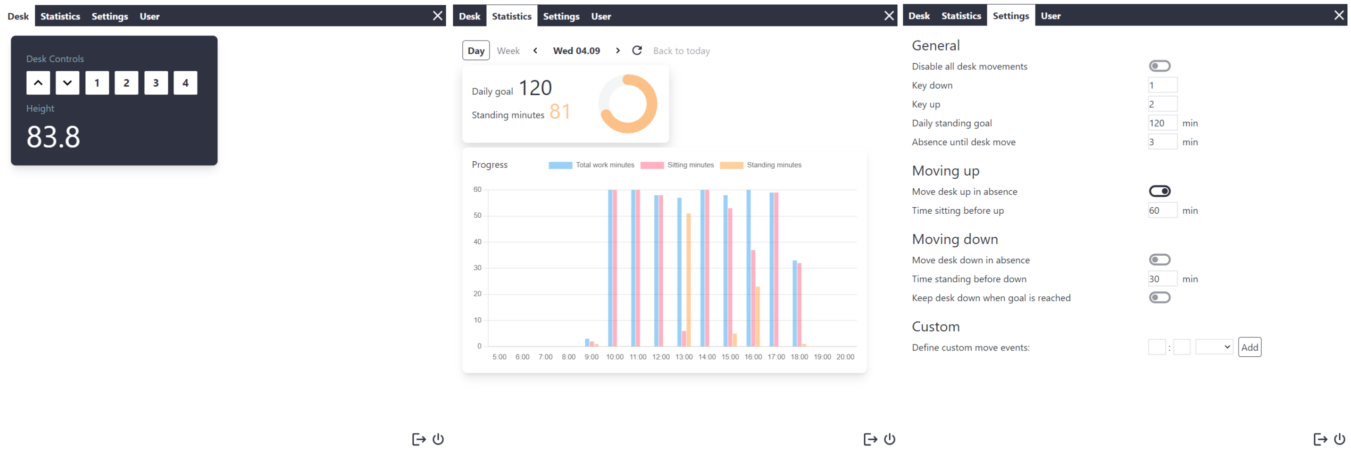
Figure 2: Control Unit with the circuit board, components, and Raspberry Pi.

3.2.2 Detecting User Presence. We used a HLK-LD2410 mmWave sensor to detect user presence. mmWave sensors can detect even small human movements such as muscle contractions or breathing. The HLK-LD2410 operates on 24GHz, with a maximum detection range of 5 meters. We set the detection range to 1.5 meters to incorporate the desk owner's space without registering far away movement in case of an open office plan. We used the default values for sensitivity and delay. We positioned the presence sensor at the edge of the board, oriented towards the working area of the desk (see Figure 1b and Figure 1c).

3.2.3 Board Design and Assembly. We designed the circuit board in Autodesk Eagle and manually soldered the components. We used a 90-degree angled pin row to orient the presence sensor outward from the board. Specifically, we utilized 4N28 optocouplers, 90-degree RJ45 sockets, and 1.2 kΩ resistors.

3.3 Pi Firmware

We used a Raspberry Pi Zero W, a low-cost single-board computer with an integrated Wi-Fi module. For initial user setup, the Pi establishes a local access point, and we implemented a small web server to establish a connection and send Wi-Fi credentials and a user ID. With this data, the Pi connects to the local network and remote server with valid authentication. Once a successful connection to the server has been established, the control unit is able to send and receive data. When a command is received (e.g., 'move up,' 'move down,' or any preset value from 1 to 4), the corresponding wires are activated, and the signal is forwarded to



(a) Virtual Keypad **(b) Statistics Page** **(c) Settings Page**

Figure 3: Overview of dashboard screens including (a) Virtual Keypad, (b) Statistics, (c) Settings.

the desk. The Pi checks every 10 seconds if either the desk height or the presence status has changed. When a change is detected, these values, together with the user ID, are published to the server. For data exchange with the server, we used Socket.IO, a widely adopted WebSocket library. The socket client receives commands and publishes custom state objects with properties, such as desk height and presence, in JSON format.

3.4 Standing Dashboard

We created a desktop application using Electron to provide statistics and configuration options for users (Figure 3).

On the initial launch, users can either log in with their username and password or create a new account. During the first login, the user is prompted to connect to the control unit's access point and enter the credentials for the local Wi-Fi network. After data transmission, the app is paired with the control unit and all other dashboard pages become accessible. The virtual keypad, shown in Figure 3a, offers the same movement buttons as the physical keypad. When a user presses any of these buttons, the command is sent to the server and then to the control unit, causing the desk to move after a very slight delay. The current height is displayed below the keys and updated in real-time.

We also implemented a statistics page (Figure 3b), which depicts bar charts of personal standing and sitting time, as well as standing goal progress. Users can select between Day and Week views and navigate time ranges for the display. By clicking on the navigation buttons for 'Day,' 'Week,' and arrows, different time ranges can be selected for display.

The settings page, divided into general, movement, and custom sections, provides options for users to define how their desk should behave (Figure 3c). Detailed explanations of each setting, as well as the system's default configuration, are listed in Table 3.

Lastly, there is a user page that simply displays the ID, name, and app version, primarily for debugging and internal use.

3.5 Server

We implemented a central server to store information, handle communication between control units and dashboards, and to remotely trigger desk transitions. In the following, we describe server endpoints, implementation, and the algorithm for desk autonomy.

3.5.1 Server Endpoints. Figure 4 provides an overview of how the dashboard, control unit, and server endpoints interact. From the dashboard, settings and user data can be both retrieved and sent to the REST API, while statistics are only fetched. The data for the statistics is pre-calculated on the server by using height and presence information stored in the database. The dashboard also connects to the socket server to receive desk height updates and to send desk move commands. The control unit connects to the socket server to receive desk move commands and to publish height and presence data. We created five tables in the database: User, for storing user credentials; Profile, for user settings; State, for desk height, presence, and corresponding timestamps; Pi Connect, for storing Pi connections; and Log, for monitoring server and user activity.

3.5.2 Implementation. We used Postgres as a relational database management system. We created Node.js projects for server endpoints, which are able to access the database using Sequelize, an object-relational mapper for JavaScript. In our REST API, we provide CRUD (Create, Read, Update, and Delete) operations for all database tables and use Express.js for creating endpoints. Using Socket.IO, we created a WebSocket server that listens to client events. Finally, we used node-schedule to run tasks at specific times or intervals.

3.5.3 Triggering Desk Movement. Every 20 seconds, a server routine verifies whether one of the users' desks needs to be moved. For each user, a decision tree (see Figure 18 in Appendix A) is traversed to determine if the desk should move and, if so, in which direction. Initially, nine setting variables and five data variables are defined. The procedure starts by checking if desk movement is generally

Table 2: Settings Defaults and Descriptions.

Setting	Default	Description
Disable all desk movements	False	When activated, the desk never moves autonomously.
Key down	1	Preset key for moving the desk down.
Key up	2	Preset key for moving the desk up.
Daily standing goal	120 min	Target number of daily standing minutes.
Absence until desk move	3 min	Minimum time the user must be absent before the desk can move.
Move desk up in absence	True	When activated, the desk moves up if the user is absent.
Time sitting before up	60 min	Minimum sitting time required before the desk can move up.
Move desk down in absence	False	When activated, the desk moves down if the user is absent.
Time standing before down	30 min	Minimum standing time required before the desk can move down.
Keep desk down when goal is reached	False	When activated, the desk stays down after the standing goal is met.
Define custom move events	[]	List of specific timestamps for moving the desk up or down.

disabled. If it is, the algorithm terminates; otherwise, it checks for custom movement events. If an event is detected, its direction is identified, and the corresponding movement command is executed. If no event is detected, the system checks whether the user has been absent for at least the duration specified in the settings. If that is the case, the system determines whether the desk is in a standing or sitting position by checking its height against a threshold of 900 cm based on prior work [63]. If the desk is in a standing position, the setting for lowering it is verified, and the current standing duration is compared to the minimum standing value in the settings. If both conditions are met, the algorithm concludes that the desk should be lowered. If the desk is in a sitting position, the algorithm checks the setting for raising it and then compares the actual sitting duration with the configured minimum. Finally, the system evaluates whether the daily standing goal has been achieved and whether the setting to keep the desk down after reaching the goal is enabled. If both conditions are true, the algorithm terminates; otherwise, the desk will be raised.

The resulting command from this decision tree is transmitted to the control unit to execute the movement. In summary, this algorithm only allows desk transitions during user absence and after a specified recovery period, except for custom movement events, which can trigger desk moves at any time.

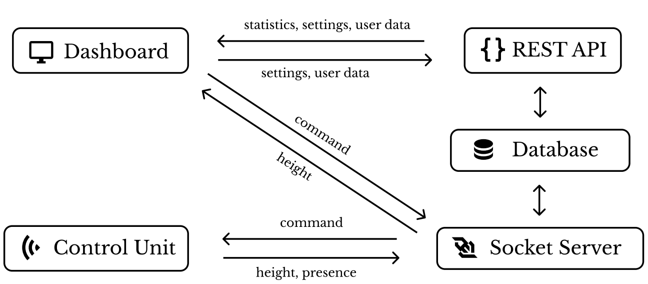


Figure 4: Networking between Server, Dashboard, and Control Unit.

3.6 Open Source

All source files (PCB design, 3D models, embedded firmware, and software) are available online for replication: https://github.com/mimuc/standing-desk-controller-2. Moreover, a static copy is available at: https://osf.io/t54a7/.

4 Study Design

We conducted a three-week within-subjects field study to evaluate our system and understand user preferences toward automated standing desks. We deployed the system in real workplaces to gain insights with high ecological validity. All participants completed an initial control week with no autonomous desk movements, followed by two weeks with full functionality.

4.1 Procedure

We introduced the participants to the study and obtained informed consent. We then installed a controller on each participant's desk and had them assign a preferred sitting and standing height to two of the preset buttons if they were not already set. The participants then completed a pre-study questionnaire to collect demographics and previous standing desk usage. All participants completed a one-week baseline where our system recorded height information, but did not move the desk autonomously. Following the baseline, the participants completed a mid-study questionnaire and then used the Standtroller for two weeks. Finally, the participants answered a post-study questionnaire and participated in an exit interview. An overview of the study procedure is depicted in Figure 5. We instructed the participants to use their desk normally in the baseline week and to adjust the settings to their liking during the active weeks. All participants were required to complete three full work weeks of data (i.e., 15 study days). If participants missed a day of interaction with the desk for any reason, such as working from home, their participation was extended by a day.

4.2 Measures and Analysis

We collected data via system logs, questionnaires, and interviews. All questionnaires and interview questions are included in the supplementary material.

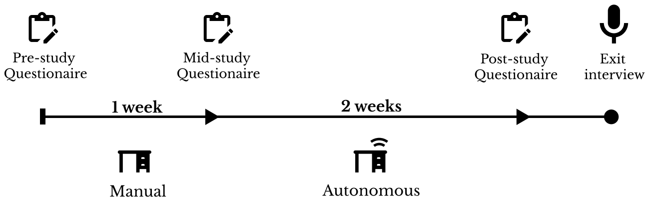


Figure 5: Study Procedure: Participants complete a pre-study questionnaire followed by a one-week baseline. Participants then complete a mid-study questionnaire and use the autonomous desk for two weeks. Finally, they complete a post-study questionnaire and an exit interview.

We measured user presence using the mmWave sensor and desk height directly from the motor module on the desks. These measures enabled us to calculate daily durations of sitting and standing. We analyzed the portion of time spent in sitting and standing positions, the number of transitions between sitting and standing, and the time between automated desk raises and manual lowering actions. We performed nested ANOVA procedures to analyze the results with Bonferroni-corrected post-hoc pairwise t-tests where appropriate.

For the questionnaire results, we analyzed the standard scales (User Experience Questionnaire (UEQ) [57], AttrakDiff [33], and System Usability Scale (SUS) [10]) based on their documentation. In line with Haliburton et al. [30], we collected Likert-scale responses to positive (motivation to stand, motivation to be active, goal accomplishment, and likelihood to use the system in the future) and negative perceptions (frustration, stress, interruption, and feeling forced to stand), and asked them to estimate their standing time. It is important to note that these Likert responses are not validated questionnaires, but are consistent with prior work [30]. We used ANOVA procedures to analyze the responses. Where applicable, post-hoc pairwise t-tests were performed with Bonferroni corrections.

Finally, we collected qualitative feedback both through open-ended questions in the questionnaires and through interviews. We recorded all interviews with consent and transcribed them verbatim. One author independently coded the interview materials using Atlas.ti[1] analysis software. Based on the exploratory nature of the study and the small sample size we followed a reflexive thematic analysis in which themes were developed inductively through iterative engagement with the data [7]. As reflexive thematic analysis treats the researcher's interpretation as the primary analytic tool, inter-rater reliability is epistemologically incompatible with the approach and was therefore not applied[8].

4.3 Participants

We recruited 13 participants, aged 28-32 years, $M = 29.8$, $SD = 1.46$ (6 female, 6 male, 1 non-binary). We used snowball sampling to identify and recruit individuals who were already standing desk users. Ten of the participants had been using a standing desk for over one year, two between six months and one year, and one for less than one month. As motivation for using a standing desk, seven participants cited health-related factors, three mentioned improved concentration, and three noted that they use it simply because their employer provided it. All participants used Kerkmann desks purchased by their employers.

[1] https://atlasti.com

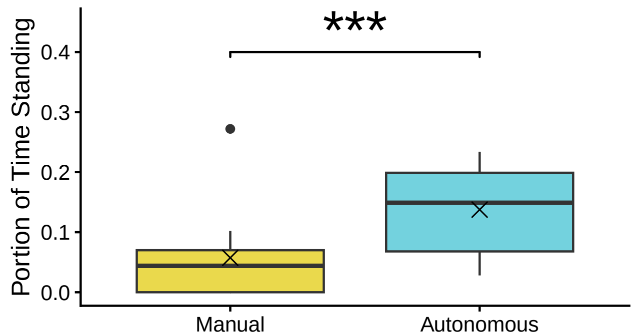


Figure 6: Portion of time spent standing. Participants stood significantly more in the autonomous phase compared to the manual condition.

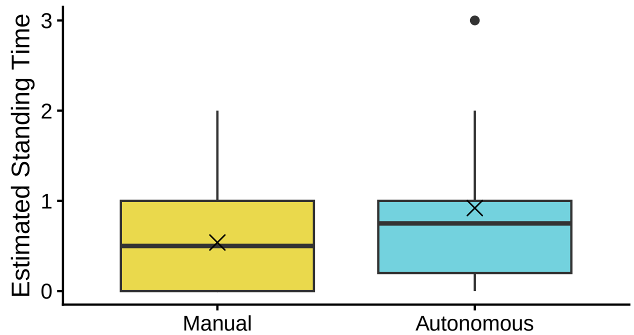


Figure 7: Participant estimations of the number of hours spent standing per day. There are no significant differences.

5 Results

We collected both quantitative and qualitative data from various sources to investigate users' experience with an autonomous standing desk. We first analyze the log data from the controller, and then the quantitative data from the surveys. The post-study interviews lasted an average of 16.8 minutes ($SD = 6.8min$). We present the exit interview results alongside the quantitative results, where appropriate.

5.1 Standing Time

Figure 17 depicts the portion of time participants spent standing during the manual and autonomous study phases. The results reveal a notable increase in standing activity during the autonomous phase. On average, participants stood for 5.7% of the workday in the manual phase and 13.8% in the autonomous phase. Figure 6 shows the portion of time spent standing in both conditions. After no substantial deviation from normality according to a Shapiro-Wilk test ($W = .95$, $p = .667$) was shown, we performed a repeated-measures ANOVA, which revealed a significant effect ($F(1, 12) = 18.978$,

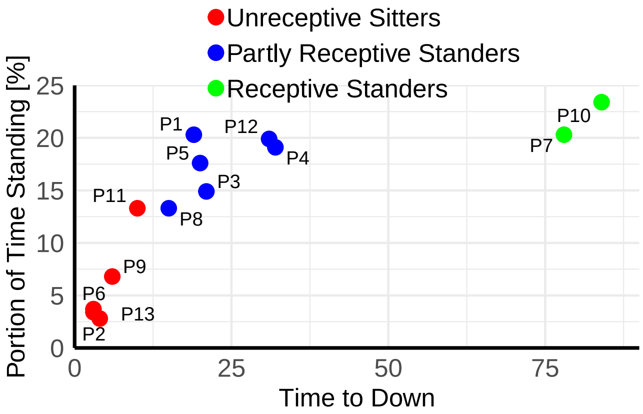


Figure 8: Plot with three groups for time to down and proportion of standing time.

$p < .001$, $\eta^2_G = .242$). This indicates a significant increase in the portion of time spent standing in the autonomous phase compared to baseline. We asked participants to estimate the time they spent standing, shown in Figure 7. While no substantial deviation from normality according to a Shapiro-Wilk test ($W = .91$, $p = .181$), a repeated-measures ANOVA showed no significant differences ($F(1, 12) = 3.024$, $p = .107$, $\eta^2_G = .062$).

We compared the time between an autonomous desk raise and the next desk lower ("time to down") with the portion of time spent standing. We clustered the resulting data using K-Means with three centers. As shown in Figure 8, we identified three distinct groups: "Unreceptive Sitters" who tend to move their desk back to sitting position quickly and have the lowest standing portions, "Partly Receptive Standers" who stood longer after a desk raise and had higher standing portions, and finally "Receptive Standers" who accepted the standing position for long periods and stood the most. To assess the separability of the exploratory profiles, we computed silhouette widths for the three-cluster solution, yielding an average silhouette width of 0.63, indicating moderate cluster separation despite the limited sample size. Pearson correlation assumptions were assessed prior to analysis; however, we found them to be violated. Therefore, we performed a Spearman's rank correlation coefficient, which revealed an association between "time to down" and "portion of time spent standing," $\rho = .904$, $p < .001$.

5.2 Use of Statistics Page

We calculated the number of hours in which participants viewed the statistics page at least once. Again, we clustered the participants using K-Means with three centers. As shown in Figure 9, we identified three groups: "Statistics Ignoring Sitters" who rarely checked the statistics page and had the lowest standing time, "Low Statistics Standers" who also had low engagement with statistics but have notably higher standing portions, and finally "Statistics Checking Standers" who checked statistics frequently and stood the most. Interestingly, "Unreceptive Sitters" and "Statistics Ignoring Sitters" consist of the same participants. To assess the separability of the exploratory profiles, we computed silhouette widths for the three-cluster solution, yielding an average silhouette width of 0.54, indicating moderate cluster separation despite the limited sample size. Pearson correlation assumptions were assessed prior to analysis; however, we found them to be violated. Therefore, we performed a Spearman's rank correlation coefficient, which revealed a non-significant positive correlation between "Hours With at Least One Statistical Check" and "Portion of Time Standing," $\rho = .255$, $p = .4$.

We gathered additional insights in the exit interviews on how users perceived the statistics page. Some found it motivating:

> *"It was nice to see the weekly stats, how much I stood. I think it was kind of encouraging and was definitely a motivating part of the app."* (P1)

However, some other participants forgot about the statistics page and were not prompted to revisit it:

> *"When I installed the app, I had a look at it, but then I closed it and forgot about it." (P3)*

5.3 Usability and User Experience

We used the SUS to assess system usability, as shown in Figure 10. The average scores, 89.6 for manual and 75.4 for autonomous, are both classified as usable according to the documentation. After a Shapiro-Wilk test ($W = 0.76$, $p = 0.003$) revealed that the data is not normally distributed, we performed a Wilcoxon signed-rank test, which revealed a significantly higher score for the manual desk compared to the autonomous desk ($V = 88$, $p < .001$, $r = 0.84$). We administered the AttrakDiff questionnaire to evaluate the system's pragmatic and hedonic qualities. We found no significant effects (Figure 11). Finally, we used the UEQ to assess user experience. As depicted in Figure 12, we found a significant effect for the novelty sub-scale (Shapiro-Wilk test: $W = 0.94$, $p = 0.449$, ANOVA: $F(1, 12) = 5.446$, $p = .038$, $\eta^2_G = .154$).

5.4 User Perceptions

Figure 13 and 14 show the participants' perception of their current standing behavior and their wishes for the future. There were no significant differences in either case (current: $V = 10$, $p = 0.188$, $r = 0.38$; future: $V = 0$, $p = 0.125$, $r = 0.33$).

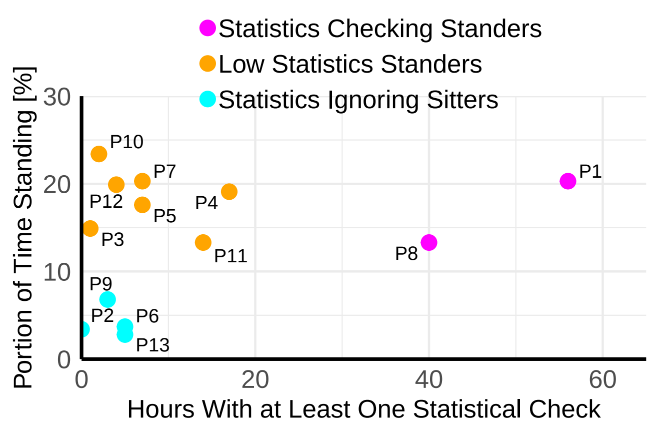


Figure 9: Plot with three groups for statistical checks and proportion of standing time.

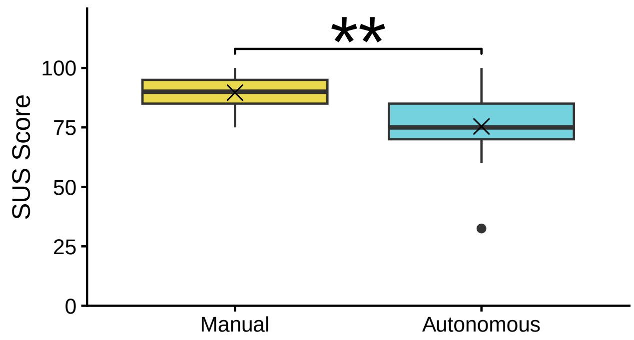


Figure 10: SUS scores for the manual and autonomous desk. There is a significant effect.

We evaluated users' positive and negative perceptions of the manual and autonomous desks. Figure 15 depicts results for positive perception. As Motivation was not normally distributed (Shapiro-Wilk: $W = 0.84$, $p = 0.019$), using a Wilcoxon signed-rank test, we found a significant increase of Motivation ($V = 0$, $p = 0.008$, $r = 0.76$). Activeness had no substantial deviation from normality according to a Shapiro-Wilk test ($W = 0.92$, $p = 0.257$). Thus, we performed an ANOVA, which revealed a significant difference ($F(1, 12) = 9.903$, $p < 0.01$, $\eta^2_G = .270$). However, there was no difgnifcant different for Goals (Shapiro-Wilk test: $W = 0.94$, $p = 0.449$, ANOVA: $F(1, 12) = 1.$, $p = .337$, $\eta^2_G = .025$) and Future (Shapiro-Wilk test: $W = 0.96$, $p = 0.681$, ANOVA: $F(1, 12) = .293$, $p = .598$, $\eta^2_G = .006$).

For the negative perceptions, shown in Figure 16. We found no substantial deviation from normality according to a Shapiro-Wilk test ($W = .96$, $p = .707$); afterward, an ANOVA revealed a significant effect for Frustration ($F(1, 12) = 13.$, $p < 0.01$, $\eta^2_G = .285$). Interruption was not a substantial deviation from normality according to a Shapiro-Wilk test ($W = 0.91$, $p = 0.162$). An ANOVA revealed a significant effect ($F(1, 12) = 11.339$, $p < 0.01$, $\eta^2_G = .287$). Similarity for Forcing (Shapiro-Wilk test: $W = 0.93$, $p = 0.323$), for an ANOVA revealed a significant effect ($F(1, 12) = 14.980$, $p < 0.01$, $\eta^2_G = .346$). However, an ANOVA revealed no significant

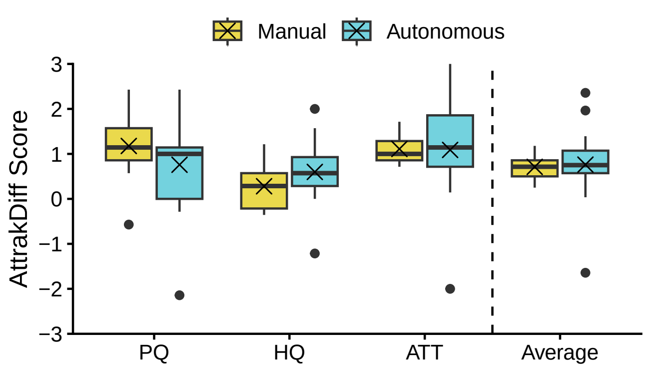


Figure 11: AttrakDiff results, divided into hedonic and pragmatic attributes, showing no significant effect.

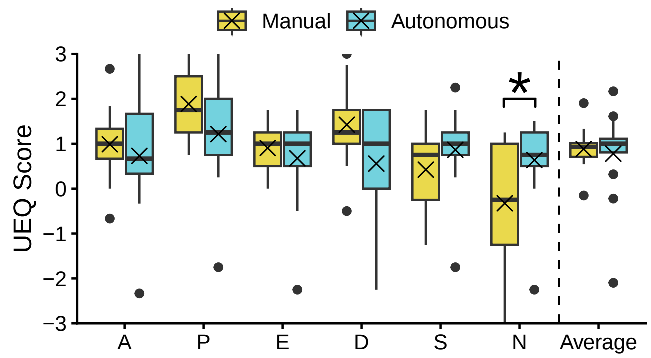


Figure 12: UEQ: Attractiveness (A), Perspicuity (P), Efficiency (E), Dependability (D), Stimulation (S), and Novelty (N). There is a significant effect for Novelty.

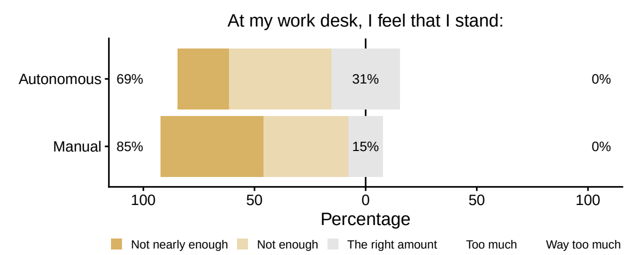


Figure 13: Feelings towards current standing time.

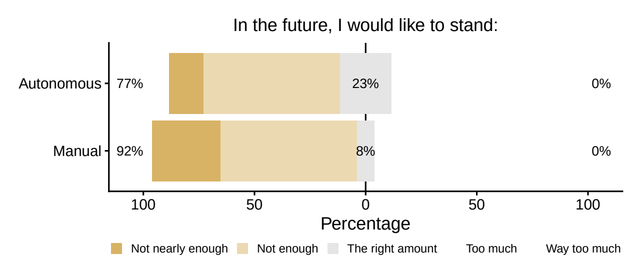


Figure 14: Goals for future standing time.

differences for Stress (Shapiro-Wilk: $W = 0.94$, $p = 0.406$, ANOVA: $F(1, 12) = 2.161$, $p < .167$, $\eta^2_G = .048$).

In the exit interview, we also asked participants if they felt forced by the anonymous desk. Four participants (P2, P5, P8, P9) felt forced or under some pressure to stand up from the desk. For three participants (P3, P7, and P11), it was not a force but a nudge to stand more. The remaining six participants (46%) did not feel a force or urge asserted by the desk.

We additionally gathered both positive and negative user perceptions in the exit interviews. Users generally appreciated that the desk moved in their absence and provided them with opportunities to stand:

> *"So what I really liked was that it created these really easy opportunities for me to use it in the standing mode, since it basically moved up when I was out of the room, or at least not at the desk. So sometimes when I would*

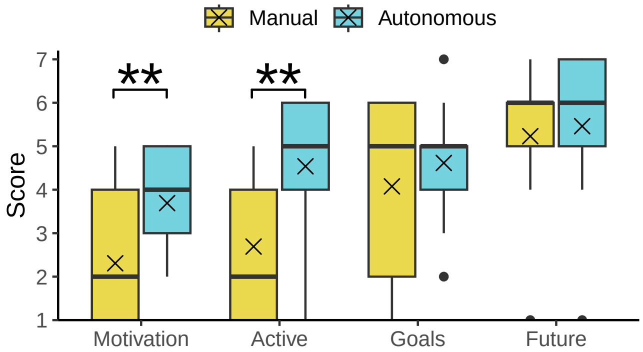


Figure 15: Positive perceptions. There is a significant effect for Motivation and Activeness.

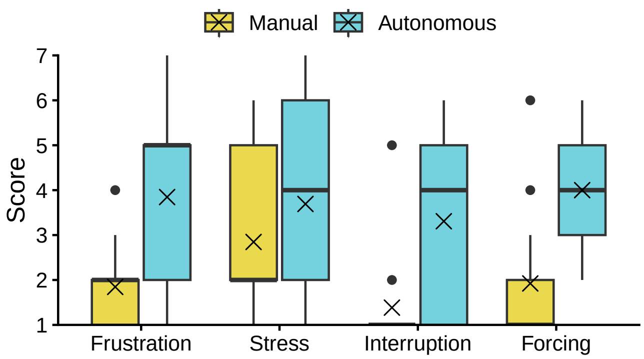


Figure 16: Negative perceptions. There is a significant effect for Frustration, Interruption, and Forcing.

> *come back, I thought, sure, why not stand for a while"* (P1)

Other participants did not fully appreciate the desk raise, but it was no effort for them to move it down again:

> *"I came back to a desk that was standing after lunch, or after I went to the bathroom. But when I noticed it, I just pressed the button down. It basically took one additional step to get back to work. But it wasn't an annoying step."* (P6)

For some participants, it felt more like an obligation they had to follow, which sometimes led to frustration:

> *"Whenever I had to go somewhere, the desk would go up again. So I had to put it down, and that always distracted me from my work."* (P2)

In some cases, the desk moving on its own was a reminder to users that their desk has standing capabilities, and inspired them to make use of it:

> *"Every time the desk moved up on its own, it made me think about how I structure my day and where I could integrate standing."* (P4)

5.5 System Settings

Only five participants (P5, P7, P8, P11, and P13) adjusted the settings; all others relied on the default configuration. Most changes were made on the first day of the autonomous phase. Responses in the interview confirm and shed light on these records.

Participants mentioned a lack of time as motivation for leaving the default settings:

> *"I didn't want to look at the app because I didn't have time for that, or I didn't take the time at least."* (P2)

Other participants were uncertain about how to change configuration values:

> *"I thought about changing it, but it felt tedious. Like if I put in six minutes here, is that enough? I don't know what time to choose here. So I just leave it like it is."* (P4)

5.6 Improvements

We asked participants if they could imagine using the autonomous system from now on, and 11/13 participants answered "yes." However, all participants suggested improvements that they would like to have in a future system.

A common desire expressed was for the desk to learn patterns and adapt to behavior:

> *"Maybe the system can check my habit and maybe analyze a little bit and try to adapt to my person."* (P12)

Participants also suggested calendar integrations to give the system more knowledge about their schedule, and therefore know when to move up or down:

> *"I would actually love to tie it to my calendar [...] if you see a specific type of appointment in my calendar, which is a meeting, go up."* (P4)

Moreover, several participants mentioned that they would like to have notifications that suggest standing or provide feedback on standing goals:

> *"I missed a reminder to get up when I was sitting for an extended period of time. Because there were times when I was sitting for two hours of writing, and it would not go up."* (P8)

Finally, some participants suggested that **gamification and social connectivity** could increase their standing motivation.

> *"I like having a competition board and a way to share your goals with your friends."* (P8)

6 Design Recommendations

Our results showed that an autonomous standing desk that transitions in the absence encouraged users to stand more, but proactive feedback and a simplified configuration could better support users' standing goals. We expand upon our findings in the following concrete design recommendations.

6.1 Desk Transitions in Absence are an Appreciated Nudge

Participants reported that the desk did not interfere with their tasks when it moved in their absence, and arriving at an elevated desk

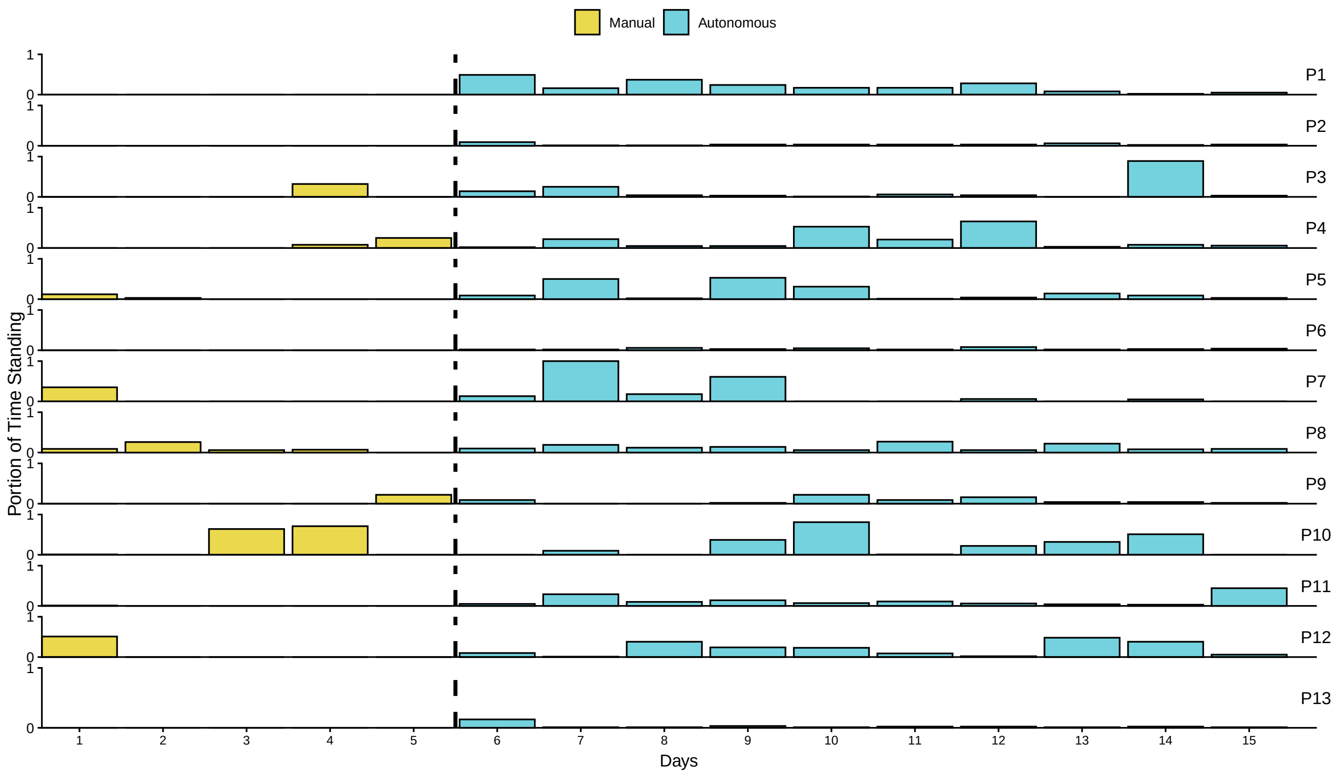


Figure 17: Portion of time spent standing for participant on each active day during both the Manual and Autonomous phases. A full day of standing is represented as 1, while no standing is represented as 0.

was often accepted. This aligns with past work investigating optimal moments for desk transitions [30, 45]. The mmWave presence sensor proved to be an effective technology for detecting intervals during which users were absent from the desk. Participants reported no false negative detections during the study, which is highly important as the occurrence of false negatives would lead to desk transitions at inconvenient times. However, when evaluating the results, we found that some false positive detections occurred, for example, in the middle of the night, even though no user was present at the desk. These should be identified and removed in future iterations to ensure that standing statistics are displayed correctly, but are already straightforward to filter out in the current format.

6.2 Configuration Must Be Intuitive and Actively Suggested

Only some participants took the initiative to change settings, predominantly on the first day of the study. Interview responses suggest a need to simplify the configuration and remind users to revisit it. One way to implement this would be a simple popup at the beginning of the day asking, "Would you like to stand more or less than yesterday?" Based on the user's responses, the desk could adjust its behavior over time. Similarly, the system could identify manual desk adjustments and ask for feedback, such as, "Would you like to sit longer before standing up?" This approach removes the need for users to think about exact values, allowing them to answer simple 'yes' or 'no' questions instead.

6.3 Adapt Desk Behavior Through Intelligent Systems

Another approach to solve the issue of users not personalizing the desk behavior would be for the system to dynamically adjust the settings on its own. This aligns with statements from participants saying that they want their desks to automatically adapt to their behavior. To achieve this, an AI model could be trained with user related data, such as presence, desk height, keypad usage and dashboard interactions. Over time, the model could identify suitable desk configurations for individual users. There are already research projects in related health-focused domains exploring how machine learning techniques and predictive models can influence motivation [5] and enable dynamic goal setting [66]. Personalization could be further improved by connecting the user's calendar with the system, allowing it to retrieve time- and context-related information.

6.4 Proactive Feedback on Standing Time Could Help Reflection

Our participants noted that the statistics in the dashboard were motivating, but many users forgot to check them. We suggest preserving the general overview of standing time, but additionally providing proactive feedback on standing progress. This could be realized via notifications with reinforcements like "Yesterday you stood longer than usual. Keep up the good work!" or friendly warnings like "You sat for 3 hours in a row, how about standing up?" Past work has shown that such notifications can increase the amount of sit-stand transitions and can contribute to overall standing time [58, 59]. Additionally, we suggest enriching the dashboard with gamification elements such as daily challenge completion charts, progress bars, streaks, badges etc. as it has proven beneficial as a habit-forming method [34, 36, 37, 46]. It is worth noting that the gamification elements need to be implemented with care and tested with users to see if they are accepted and effective.

6.5 Limitations & Future Work

There are several limitations to our study design. Firstly, participants had varying daily office working hours, meaning some spent notably more time at their desks compared to others. Additionally, some participants missed certain study days due to working from home or being on vacation, which required us to extend the study period by a few days for those users. Participants also reported experiencing varying levels of stress during the study from work-related challenges, which may have influenced their engagement with our system. We chose not to analyze the effects of these factors as they arose randomly. While we cannot determine whether these factors affected the study results, we argue that the ecological validity gained by conducting our study in the field outweighs the potential downsides of confounding external factors.

We conducted our study over a period of three weeks, which is too short to measure long-term behaviors and trends [1]. Consequently, we cannot comment on the effectiveness of our system in enacting long-term behavior change. However, we selected a duration that was practical to conduct while aiming to allow participants to overcome novelty effects. We recommend that future studies extend to at least six weeks to allow for new habits to develop [40]. This extended study would also reduce the influence of external factors, such as work-related stress or office absences, since they should balance out over longer periods of time. Additionally, while we found a significant increase in standing time, participants still had a lower average portion of time compared to the 26% recommended by Kar and Hedge [38]. Another future study is required to understand whether the increase in standing time from a system like ours has clinically meaningful health benefits for users.

Another potential limitation of our study design is the sequential order of the conditions. All participants did a baseline first, followed by an active period. While counter-balancing the conditions would be sensible if we had multiple difference active conditions, in this case we one implemented a baseline condition and a single active condition. All of the participants were already standing desk users, so doing the baseline condition first was the best way to capture participants' natural desk interaction behaviors.

We also identified some improvements to our board design and implementation. For instance, we experienced some connection issues between the control unit and the server, which may have been caused by hardware limitations of the Raspberry Pi Zero or by the instability of the local Wi-Fi networks. When building upon the current prototype, reliable network adapters should be utilized, and stable Wi-Fi networks should be ensured in every office for future studies. An additional hardware constraint is that our controller is not universally applicable. Some manufacturers use two-button keypads or paddle-style controllers, both of which are not inherently compatible with our control unit. However, our design could be adapted to other desk configurations while using the same conceptual approach for control.

7 Conclusion

In this work, we designed, implemented, and evaluated an open-source plug-and-play system that autonomously adjusts the height of standing desks while users are absent. We developed a desk-attached control unit that measures user presence and adjusts desk height, a desktop application to visualize standing time and provide a configuration interface, and a back-end. To evaluate our design, we conducted a three-week field study with standing desk users to measure standing time, track application usage, and gather qualitative feedback. Our results show that users stood significantly more with the Standtroller, but proactive feedback and a simplified configuration are needed to better support users' standing goals. We contribute our open-source system and concrete design recommendations for developers of future systems. Our work provides insights on how autonomous office furniture can motivate users to be more active at the workplace, which can mitigate the health risks associated with prolonged sedentary work time.

Open Science

We encourage readers to reproduce and extend our results and analysis methods. Therefore, our experimental setup collected datasets, and analysis scripts are openly available on the Open Science Framework (https://osf.io/t54a7/). Additional the code for the Standtroller is available at: https://github.com/mimuc/standing-desk-controller-2.

References

[1] Henk Aarts, Theo Paulussen, and Herman Schaalma. 1997. Physical exercise habit: on the conceptualization and formation of habitual health behaviours. *Health Education Research* 12, 3 (1997), 363–374. https://doi.org/10.1093/her/12.3.363

[2] Aino Ahtinen, Eeva Andrejeff, Christopher Harris, and Kaisa Väänänen. 2017. Let's walk at work: persuasion through the brainwolk walking meeting app. In *Proceedings of the 21st International Academic Mindtrek Conference on - AcademicMindtrek '17*. ACM Press, Tampere, Finland, 73–82. https://doi.org/10.1145/3131085.3131098

[3] A. Ahtinen, E. Andrejeff, M. Vuolle, and K. Väänänen. 2016. Walk as You Work: User Study and Design Implications for Mobile Walking Meetings. In *NordiCHI '16: Proceedings of the 9th Nordic Conference on Human-Computer Interaction*. ACM, Gothenburg, Sweden, 1–10. https://doi.org/10.1145/2971485.2971510

[4] Aino Ahtinen, Eeva Andrejeff, and Kaisa Väänänen. 2016. Brainwolk: a mobile technology mediated walking meeting concept for wellbeing and creativity at work. In *Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia (MUM '16)*. Association for Computing Machinery, Rovaniemi, Finland, 307–309. https://doi.org/10.1145/3012709.3016062

[5] Anil Aswani, Philip Kaminsky, Yonatan Mintz, Elena Flowers, and Yoshimi Fukuoka. 2019. Behavioral modeling in weight loss interventions. *European Journal of Operational Research* 272, 3 (Feb. 2019), 1058–1072. https://doi.org/10.1016/j.ejor.2018.07.011

[6] Sadegh Baradaran Mahdavi, Roya Riahi, Babak Vahdatpour, and Roya Kelishadi. 2021. Association between sedentary behavior and low back pain; A systematic review and meta-analysis. *Health Promotion Perspectives* 11, 4 (Dec. 2021), 393–410. https://doi.org/10.34172/hpp.2021.50

[7] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (2006), 77–101. https://doi.org/10.1191/1478088706qp063oa

[8] Virginia Braun and Victoria Clarke. 2021. One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qualitative Research in Psychology* 18, 3 (2021), 328–352. https://doi.org/10.1080/14780887.2020.1769238

[9] Hans Brombacher, Xipei Ren, Steven Vos, and Carine Lallemand. 2020. Visualizing Computer-Based Activity on Ambient Displays to Reduce Sedentary Behavior at Work. In *32nd Australian Conference on Human-Computer Interaction (OzCHI '20)*. Association for Computing Machinery, New York, NY, USA, 760–764. https://doi.org/10.1145/3441000.3441022

[10] John Brooke. 1996. SUS: A 'Quick and Dirty' Usability Scale. In *Usability Evaluation In Industry*. CRC Press.

[11] John P. Buckley, Alan Hedge, Thomas Yates, Robert J. Copeland, Michael Loosemore, Mark Hamer, Gavin Bradley, and David W. Dunstan. 2015. The sedentary office: an expert statement on the growing case for change towards better health and productivity. *British Journal of Sports Medicine* 49, 21 (Nov. 2015), 1357–1362. https://doi.org/10.1136/bjsports-2015-094618

[12] Scott A. Cambo, Daniel Avrahami, and Matthew L. Lee. 2017. BreakSense: Combining Physiological and Location Sensing to Promote Mobility during Work-Breaks. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17)*. Association for Computing Machinery, New York, NY, USA, 3595–3607. https://doi.org/10.1145/3025453.3026021

[13] April J. Chambers, Michelle M. Robertson, and Nancy A. Baker. 2019. The effect of sit-stand desks on office worker behavioral and health outcomes: A scoping review. *Applied Ergonomics* 78 (July 2019), 37–53. https://doi.org/10.1016/j.apergo.2019.01.015

[14] Josephine Y Chau, Michelle Daley, Anu Srinivasan, Scott Dunn, Adrian E Bauman, and Hidde P Van Der Ploeg. 2014. Desk-based workers' perspectives on using sit-stand workstations: a qualitative analysis of the Stand@Work study. *BMC Public Health* 14, 1 (Dec. 2014), 752. https://doi.org/10.1186/1471-2458-14-752

[15] Stacy Clemes, Sophie O'Connell, and Charlotte L. Edwardson. 2014. Office workers objectively measured sedentary behavior and physical activity during and outside working hours. *Journal of Occupational and Environmental Medicine* 56, 3 (Jan. 2014), 298–303. https://repository.lboro.ac.uk/articles/Office_workers_objectively_measured_sedentary_behavior_and_physical_activity_during_and_outside_working_hours/9624851

[16] Dianne ACM Commissaris, Maaike A Huysmans, Svend Erik Mathiassen, Divya Srinivasan, Lando LJ Koppes, and Ingrid JM Hendriksen. 2016. Interventions to reduce sedentary behavior and increase physical activity during productive work: a systematic review. *Scandinavian Journal of Work, Environment & Health* 42, 3 (2016), 181–191. http://www.jstor.org/stable/43999217

[17] Vicki S. Conn, Adam R. Hafdahl, Pamela S. Cooper, Lori M. Brown, and Sally L. Lusk. 2009. Meta-analysis of workplace physical activity interventions. *American Journal of Preventive Medicine* 37, 4 (Oct. 2009), 330–339. https://doi.org/10.1016/j.amepre.2009.06.008

[18] Ida Damen, Hans Brombacher, Carine Lallemand, Rens Brankaert, Aarnout Brombacher, Pieter van Wesemael, and Steven Vos. 2020. A Scoping Review of Digital Tools to Reduce Sedentary Behavior or Increase Physical Activity in Knowledge Workers. *International Journal of Environmental Research and Public Health* 17, 2 (Jan. 2020), 499. https://doi.org/10.3390/ijerph17020499

[19] Ida Damen, Lidewij Heerkens, Annabel van den Broek, Kimberly Drabbels, Olga Cherepennikova, Hans Brombacher, and Carine Lallemand. 2020. PositionPeak: Stimulating Position Changes During Meetings. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems (CHI EA '20)*. Association for Computing Machinery, New York, NY, USA, 1–8. https://doi.org/10.1145/3334480.3383054

[20] Ida Damen, Anika Kok, Bas Vink, Hans Brombacher, Steven Vos, and Carine Lallemand. 2020. The Hub: Facilitating Walking Meetings through a Network of Interactive Devices. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference (DIS' 20 Companion)*. Association for Computing Machinery, New York, NY, USA, 19–24. https://doi.org/10.1145/3393914.3395876

[21] Ida Damen, Carine Lallemand, Rens Brankaert, Aarnout Brombacher, Pieter van Wesemael, and Steven Vos. 2020. Understanding Walking Meetings: Drivers and Barriers. In *CHI*. ACM, Honolulu, HI, USA, 14. https://doi.org/10.1145/3313831.3376141

[22] Ida Damen, Ingmar Nieuweboer, Hans Brombacher, Pieter van Wesemael, Steven Vos, and Carine Lallemand. 2021. The Office Jungle: Exploring Unusual Ways of Working through Bodily Experimentations. In *Designing Interactive Systems Conference 2021 (DIS '21)*. Association for Computing Machinery, New York, NY, USA, 466–477. https://doi.org/10.1145/3461778.3462062

[23] Keith M. Diaz, Virginia J. Howard, Brent Hutto, Natalie Colabianchi, John E. Vena, Monika M. Safford, Steven N. Blair, and Steven P. Hooker. 2017. Duration of Sedentary Episodes Is Associated With Risk for Death. *Annals of Internal Medicine* 167, 7 (Oct. 2017), I–24. https://doi.org/10.7326/P17-9045

[24] Keith M. Diaz, Virginia J. Howard, Brent Hutto, Natalie Colabianchi, John E. Vena, Monika M. Safford, Steven N. Blair, and Steven P. Hooker. 2017. Patterns of Sedentary Behavior and Mortality in U.S. Middle-Aged and Older Adults: A National Cohort Study. *Annals of Internal Medicine* 167, 7 (Oct. 2017), 465–475. https://doi.org/10.7326/M17-0212

[25] Earl S. Ford and Carl J. Caspersen. 2012. Sedentary behaviour and cardiovascular disease: a review of prospective studies. *International Journal of Epidemiology* 41, 5 (Oct. 2012), 1338–1353. https://doi.org/10.1093/ije/dys078

[26] Jutta Fortmann, Tim Claudius Stratmann, Susanne Boll, Benjamin Poppinga, and Wilko Heuten. 2013. Make me move at work! An ambient light display to increase physical activity. In *2013 7th International Conference on Pervasive Computing Technologies for Healthcare and Workshops*. IEEE, Venice, Italy, 274–277. https://doi.org/10.4108/icst.pervasivehealth.2013.252089

[27] Kazuyuki Fujita, Aoi Suzuki, Kazuki Takashima, Kaori Ikematsu, and Yoshifumi Kitamura. 2021. TiltChair: Manipulative Posture Guidance by Actively Inclining the Seat of an Office Chair. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (CHI '21)*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3411764.3445151

[28] Nicholas D. Gilson, Caitlin Hall, Angela Renton, Norman Ng, and William von Hippel. 2017. Do Sitting, Standing, or Treadmill Desks Impact Psychobiological Indicators of Work Productivity? *Journal of Physical Activity and Health* 14, 10 (Oct. 2017), 793–796. https://doi.org/10.1123/jpah.2016-0712

[29] Luke Haliburton, Natalia Bartłomiejczyk, Albrecht Schmidt, Paweł W. Woźniak, and Jasmin Niess. 2023. The Walking Talking Stick: Understanding Automated Note-Taking in Walking Meetings. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 431, 16 pages. https://doi.org/10.1145/3544548.3580986

[30] Luke Haliburton, Saba Kheirinejad, Albrecht Schmidt, and Sven Mayer. 2023. Exploring Smart Standing Desks to Foster a Healthier Workplace. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 7, 2 (June 2023), 57:1–57:22. https://doi.org/10.1145/3596260

[31] Luke Haliburton and Albrecht Schmidt. 2020. Technologies for healthy work. *Interactions* 27, 3 (April 2020), 64–66. https://doi.org/10.1145/3386391

[32] Luke Haliburton, Pawel W. Wozniak, Albrecht Schmidt, and Jasmin Niess. 2021. Charting the Path: Requirements and Constraints for Technology-Supported Walking Meetings. *Proceedings of the ACM on Human-Computer Interaction* 5, CSCW2 (Oct. 2021), 347:1–347:31. https://doi.org/10.1145/3476088

[33] Marc Hassenzahl, Michael Burmester, and Franz Koller. 2003. AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität. In *Mensch & Computer 2003: Interaktion in Bewegung*, Gerd Szwillus and Jürgen Ziegler (Eds.). Vieweg+Teubner Verlag, Wiesbaden, 187–196. https://doi.org/10.1007/978-3-322-80058-9_19

[34] Changiz Hosseini, Oda Humlung, Asle Fagerstrøm, and Moutaz Haddara. 2022. An experimental study on the effects of gamification on task performance. *Procedia Computer Science* 196 (2022), 999–1006. https://doi.org/10.1016/j.procs.2021.12.102 International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2021.

[35] Shamsi T. Iqbal and Brian P. Bailey. 2005. Investigating the effectiveness of mental workload as a predictor of opportune moments for interruption. In *CHI '05 Extended Abstracts on Human Factors in Computing Systems*. ACM, Portland OR USA, 1489–1492. https://doi.org/10.1145/1056808.1056948

[36] Anna Iurchenko. 2017. An Exploratory Study of Health Habit Formation Through Gamification. arXiv:1708.04418 [cs.HC] https://arxiv.org/abs/1708.04418

[37] Daniel Johnson, Sebastian Deterding, Kerri-Ann Kuhn, Aleksandra Staneva, Stoyan Stoyanov, and Leanne Hides. 2016. Gamification for health and wellbeing: A systematic review of the literature. *Internet Interventions* 6 (2016), 89–106. https://doi.org/10.1016/j.invent.2016.10.002

[38] Gourab Kar and Alan Hedge. 2020. Effects of a sit-stand-walk intervention on musculoskeletal discomfort, productivity, and perceived physical and mental fatigue, for computer-based work. *International Journal of Industrial Ergonomics* 78 (July 2020), 102983. https://doi.org/10.1016/j.ergon.2020.102983

[39] Thomas Karakolis and Jack P. Callaghan. 2014. The impact of sit–stand office workstations on worker discomfort and productivity: A review. *Applied Ergonomics* 45, 3 (May 2014), 799–806. https://doi.org/10.1016/j.apergo.2013.10.001

[40] Navin Kaushal and Ryan E. Rhodes. 2015. Exercise habit formation in new gym members: a longitudinal study. *Journal of Behavioral Medicine* 38, 4 (Aug. 2015), 652–663. https://doi.org/10.1007/s10865-015-9640-7

[41] Lawrence H. Kim, Annel Amelia Leon, Ganapathy Sankararaman, Blake M. Jones, Gourab Saha, Amanda Spyropolous, Akshara Motani, Matthew Louis Mauriello, and Pablo E. Paredes. 2021. The Haunted Desk: Exploring Non-Volitional Behavior Change with Everyday Robotics. In *Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction*. Association for Computing Machinery, New York, NY, USA, 71–75. http://doi.org/10.1145/3434074.3447131

[42] Katja Koren, Rado Pišot, and Boštjan Šimunič. 2016. Active workstation allows office workers to work efficiently while sitting and exercising moderately. *Applied Ergonomics* 54 (May 2016), 83–89. https://doi.org/10.1016/j.apergo.2015.11.013

[43] Rotem Kronenberg and Tsvi Kuflik. 2019. Automatically Adjusting Computer Screen. In *Adjunct Publication of the 27th Conference on User Modeling, Adaptation and Personalization (UMAP'19 Adjunct)*. Association for Computing Machinery,

New York, NY, USA, 51–56. https://doi.org/10.1145/3314183.3324980

[44] Przemysław Kucharski, Piotr Łuczak, Izabela Perenc, Tomasz Jaworski, Andrzej Romanowski, Mohammed Obaid, and Paweł W. Woźniak. 2016. APEOW: A personal persuasive avatar for encouraging breaks in office work. In *2016 Federated Conference on Computer Science and Information Systems (FedCSIS)*. IEEE, Gdansk, Poland, 1627–1630.

[45] Bokyung Lee, Sindy Wu, Maria Jose Reyes, and Daniel Saakes. 2019. The Effects of Interruption Timings on Autonomous Height-Adjustable Desks that Respond to Task Changes. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–10. https://doi.org/10.1145/3290605.3300558

[46] Falk Lieder, Pin-Zhen Chen, Mike Prentice, Victoria Amo, and Mateo Tošić. 2024. Gamification of Behavior Change: Mathematical Principle and Proof-of-Concept Study. *JMIR Serious Games* 12 (March 2024), e43078.

[47] Yuhan Luo, Bongshin Lee, Donghee Yvette Wohn, Amanda L. Rebar, David E. Conroy, and Eun Kyoung Choe. 2018. Time for Break: Understanding Information Workers' Sedentary Behavior Through a Break Prompting System. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3173574.3173701

[48] Brittany T. MacEwen, Dany J. MacDonald, and Jamie F. Burr. 2015. A systematic review of standing and treadmill desks in the workplace. *Preventive Medicine* 70 (Jan. 2015), 50–58. https://doi.org/10.1016/j.ypmed.2014.11.011

[49] Victor Mateevitsi, Khairi Reda, Jason Leigh, and Andrew Johnson. 2014. The health bar: a persuasive ambient display to improve the office worker's well being. In *Proceedings of the 5th Augmented Human International Conference (AH '14)*. Association for Computing Machinery, New York, NY, USA, 1–2. https://doi.org/10.1145/2582051.2582072

[50] Daphne Menheere, Ida Damen, Carine Lallemand, and Steven Vos. 2020. Ivy: A Qualitative Interface to Reduce Sedentary Behavior in the Office Context. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference (DIS' 20 Companion)*. Association for Computing Machinery, New York, NY, USA, 329–332. https://doi.org/10.1145/3393914.3395822

[51] Fatemeh Moradi and Mikael Wiberg. 2017. NEAT-Lamp and Talking Tree: Beyond Personal Informatics towards Active Workplaces. *Computers* 7 (Dec. 2017), 4. https://doi.org/10.3390/computers7010004

[52] Ailsa Niven, Graham Baker, Eva Coral Almeida, Samantha G. Fawkner, Ruth Jepson, Jillian Manner, Sarah Morton, Glenna Nightingale, Divya Sivaramakrishnan, and Claire Fitzsimons. 2023. "Are We Working (Too) Comfortably?": Understanding the Nature of and Factors Associated with Sedentary Behaviour When Working in the Home Environment. *Occupational Health Science* 7, 1 (March 2023), 71–88. https://doi.org/10.1007/s41542-022-00128-6

[53] Matthew P. Normand. 2008. Increasing physical activity through self-monitoring, goal setting, and feedback. *Behavioral Interventions* 23, 4 (Nov. 2008), 227–236. https://doi.org/10.1002/bin.267

[54] E. Justin Page, Andrew S. Massey, Pedro N. Prado-Romero, and Shadi Albadawi. 2020. The Use of Self-Monitoring and Technology to Increase Physical Activity: A Review of the Literature. *Perspectives on Behavior Science* 43, 3 (Sept. 2020), 501–514. https://doi.org/10.1007/s40614-020-00260-0

[55] Alpa V. Patel, Maret L. Maliniak, Erika Rees-Punia, Charles E. Matthews, and Susan M. Gapstur. 2018. Prolonged Leisure Time Spent Sitting in Relation to Cause-Specific Mortality in a Large US Cohort. *American Journal of Epidemiology* 187, 10 (Oct. 2018), 2151–2158. https://doi.org/10.1093/aje/kwy125

[56] Lidewij R. Renaud, Maaike A. Huysmans, Hidde P. Van Der Ploeg, Erwin M. Speklé, and Allard J. Van Der Beek. 2018. Long-Term Access to Sit-Stand Workstations in a Large Office Population: User Profiles Reveal Differences in Sitting Time and Perceptions. *International Journal of Environmental Research and Public Health* 15, 9 (Sept. 2018), 2019. https://doi.org/10.3390/ijerph15092019

[57] Martin Schrepp, Jörg Thomaschewski, and Andreas Hinderks. 2017. Construction of a Benchmark for the User Experience Questionnaire (UEQ). (June 2017). https://doi.org/10.9781/ijimai.2017.445

[58] Pankaj Sharma, Adam Pickens, Ranjana Mehta, Gang Han, and Mark E. Benden. 2019. Smart Software Can Increase Sit–Stand Desk Transitions During Active Computer Use. *International Journal of Environmental Research and Public Health* 16, 13 (July 2019), 2438. https://doi.org/10.3390/ijerph16132438

[59] Pankaj Parag Sharma, Ranjana K. Mehta, Adam Pickens, Gang Han, and Mark Benden. 2019. Sit-Stand Desk Software Can Now Monitor and Prompt Office Workers to Change Health Behaviors. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 61, 5 (Aug. 2019), 816–824. https://doi.org/10.1177/0018720818807043

[60] David Sirkin, Brian Mok, Stephen Yang, and Wendy Ju. 2015. Mechanical Ottoman: How Robotic Furniture Offers and Withdraws Support. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction (HRI '15)*. Association for Computing Machinery, New York, NY, USA, 11–18. https://doi.org/10.1145/2696454.2696461

[61] Kazuki Takashima, Naohiro Aida, Hitomi Yokoyama, and Yoshifumi Kitamura. 2013. TransformTable: a self-actuated shape-changing digital table. In *Proceedings of the 2013 ACM international conference on Interactive tabletops and surfaces (ITS '13)*. Association for Computing Machinery, New York, NY, USA, 179–188. https://doi.org/10.1145/2512349.2512818

[62] Alicia A. Thorp, Genevieve N. Healy, Elisabeth Winkler, Bronwyn K. Clark, Paul A. Gardiner, Neville Owen, and David W. Dunstan. 2012. Prolonged sedentary time and physical activity in workplace and non-work contexts: a cross-sectional study of office, customer service and call centre employees. *The International Journal of Behavioral Nutrition and Physical Activity* 9 (Oct. 2012), 128. https://doi.org/10.1186/1479-5868-9-128

[63] Daniel Viggiani, Jeffery M. Barrett, Eric Will, and Jack P. Callaghan. 2021. Measurement of Sit-Stand Desk Usage by Desk-Mounted Sensors. *Ergonomics in Design: The Quarterly of Human Factors Applications* 29, 3 (July 2021), 4–10. https://doi.org/10.1177/1064804620947630

[64] Stephen Wilks, Monica Mortimer, and Per Nylén. 2006. The introduction of sit-stand worktables; aspects of attitudes, compliance and satisfaction. *Applied Ergonomics* 37, 3 (May 2006), 359–365. https://doi.org/10.1016/j.apergo.2005.06.007

[65] Emma G. Wilmot, C. L. Edwardson, F. A. Achana, M. J. Davies, T. Gorely, L. J. Gray, K. Khunti, T. Yates, and S. J. H. Biddle. 2012. Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. *Diabetologia* 55, 11 (Nov. 2012), 2895–2905. https://doi.org/10.1007/s00125-012-2677-z

[66] Mo Zhou, Yonatan Mintz, Yoshimi Fukuoka, Ken Goldberg, Elena Flowers, Philip Kaminsky, Alejandro Castillejo, and Anil Aswani. 2018. Personalizing Mobile Fitness Apps using Reinforcement Learning. *CEUR workshop proceedings* 2068 (March 2018). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7220419/

[67] Xuemei Zhu, Aya Yoshikawa, Lingyi Qiu, Zhipeng Lu, Chanam Lee, and Marcia Ory. 2020. Healthy workplaces, active employees: A systematic literature review on impacts of workplace environments on employees' physical activity and sedentary behavior. *Building and Environment* 168 (Jan. 2020), 106455. https://doi.org/10.1016/j.buildenv.2019.106455

A Appendix

Table 3: Configuration settings of the standing desk controller.

Name	Setting	Type
`movement_disabled`	Disable all desk movements	bool
`goal`	Daily standing goal	int
`min_duration_absence`	Absence until desk moves	int
`move_desk_up`	Move desk up in absence	bool
`min_sitting_before_up`	Time sitting before up	int
`move_desk_down`	Move desk down in absence	bool
`min_standing_before_down`	Time standing before down	int
`keep_down_when_goal_reached`	Keep desk down when goal is reached	bool
`custom_events`	Define custom move events	list

Table 4: Runtime variables available to the standing desk controller.

Name	Source Data	Type
`desk_height`	desk height	int
`duration_absence`	presence	int
`standing_today`	presence, desk height	int
`current_sitting_time`	presence, desk height	int
`current_standing_time`	presence, desk height	int

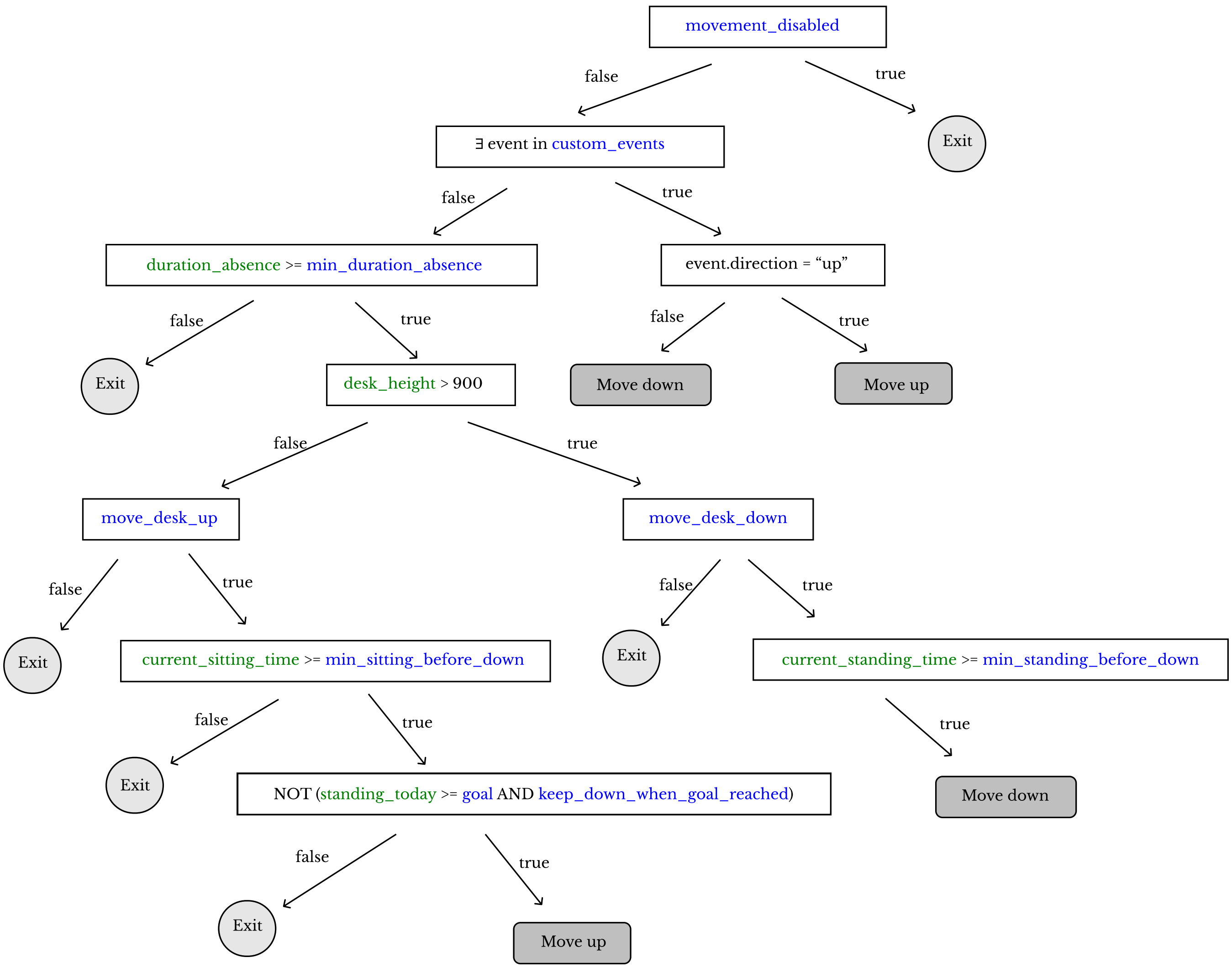


Figure 18: Decision tree for moving the desk.