Highlights

Toward Context-Aware and Personalized Sit-Stand Desk Interventions: Insights from a Field Observational Study

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- Users preferred standing for focused or interactive tasks over passive or distracting ones.
- Posture switching was not necessarily associated with a change in work tasks.
- Notifications effectively increased total standing time during work sessions.

Toward Context-Aware and Personalized Sit-Stand Desk Interventions: Insights from a Field Observational Study

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Abstract

Prolonged sitting is associated with increased chronic disease risks, making sit-stand desks a popular intervention to promote healthier behaviors among knowledge workers. While reminders can encourage desk usage, traditional notifications are often perceived as disruptive. We investigated how intelligent sit-stand desks can promote healthier behaviors with minimal disruption to productivity by understanding users' work, physical, and personal context. We conducted a 15-day observational study with knowledge workers ($N = 10$), collecting data on their sit-stand desk usage and computer activities. Participants, on average, were more likely to stand during productive (Odds Ratio = 2.75) and interactive tasks (Odds Ratio = 2.27) than when they got distracted at work. However, posture switching did not consistently align with task switching. A periodic notification every 30 minutes significantly increased standing time by 25.9 minutes per day. Semi-structured interviews revealed strong task-specific standing preferences and needs for overall context awareness, underscoring the need for personalized interventions. We present design guidelines for context-aware, personalized sit-stand desks that support both health and productivity in knowledge work.

Keywords: Sit-stand desk, Context-aware system, Health intervention

1. Introduction

Sedentary behavior is a growing concern among knowledge workers, contributing to health risks such as cardiovascular diseases [1, 2, 3], musculoskeletal pain [4], mental health issues [5, 6], and premature mortality [7, 8]. Knowledge-intensive tasks—such as writing, programming, and reading—require prolonged deep concentration, leading office workers to spend more time seated at work than during non-work hours [9, 10]. On average, students and office workers remain seated for 50 hours per week [11, 12, 13], and this trend is expected to rise, highlighting the need for effective health interventions [14].

Sit-stand desks have been promoted as an intervention to mitigate these risks by encouraging posture switching and interval standing [15, 16, 17]. However, their effectiveness depends on user commitment, and studies show that voluntary use often leads to underutilization or abandonment [18, 19, 20]. Without consistent engagement, their potential health benefits remain limited.

To encourage usage, interventions such as notifications and automatic desk adjustments have been explored [21, 22, 23, 24]. While these methods increase standing time, their impact on cognitive focus and productivity remains unclear. In human-computer interaction (HCI), notifications are known to interrupt workflow, potentially disrupting concentration and reducing productivity [25, 26, 27]. Unlike taking a break from work, posture adjustments can occur between work tasks or even while working on one task, so notifications should take into account how they might disrupt users' workflow. Therefore, we need to understand how we can balance the interruptive nature of automated notifications with their positive health benefits.

To balance health and productivity, sit-stand desk interventions should be *context-aware* and *personalized*, adapting to individual work habits, preferences, and cognitive flow. An ideal intervention should minimize disruptions while effectively promoting healthy behavior. Thus, we aim to identify contextual factors that intelligent sit-stand desk interventions should consider to maximize health benefits with minimal interference in workers' productivity.

Building on prior research on sit-stand desks [15, 18, 24, 28, 29] and self-tracking productivity tools [30, 31, 32], we investigated four key research questions (RQ) to inform the design of effective posture-based interventions:

- RQ1: Which work activities do users tend to perform while standing versus sitting?

- RQ2: Do posture switches coincide with transitions in work activity, and could these moments serve as appropriate opportunities for intervention?
- RQ3: How do users' behaviors change in response to posture-related notifications?
- RQ4: What design considerations can enhance the effectiveness of sit-stand desks in promoting productivity and healthy behaviors?

To explore these questions, we conducted a three-week field study with ten knowledge workers in a quasi-experimental setting. While sit-stand desks and notifications were controlled, participants' work environments, work activity types, and working hours remained naturalistic. We collected both quantitative and qualitative data through self-tracking tools and semi-structured interviews. Our results suggest that sit-stand desk users may not change posture at natural breakpoints, i.e., when switching tasks or taking breaks. Instead, they stand up when they want to focus more on a task, indicating that productivity and sit-stand desk usage can have a symbiotic relationship. Our findings contribute to the development of intelligent, context-aware, and personalized sit-stand desk interventions that adapt to users' physical and cognitive states, ultimately promoting both health and productivity.

2. Background

2.1. Sedentary Behavior and Its Health Risks

Sedentary behavior—defined as activities performed while sitting, reclining, or lying down—poses significant health risks. Prolonged sitting has acute negative metabolic effects (energy expenditure below 1.5 times the basal metabolic rate) [33, 34, 35], weight gain [36], body pain [4, 37], mental health issues [38], depression [39], and premature death [40]. Alarmingly, individuals who sit for 8 to 11 hours per day have a 15% higher mortality rate over the next three years compared to those who sit for less than 4 hours per day [41].

The sedentary nature of modern work, particularly among knowledge workers, has led to prolonged desk-based activities. In the U.S., adults spend approximately 25.7% of their 8-hour workday seated, and 44.5% engage in less than 150 minutes of leisure-time physical activity per week [42]. This trend extends globally, with sedentary time rising across work, leisure, and transportation domains [43, 44, 45]. Physical inactivity at work is expected to persist among knowledge workers, with sedentary behavior likely continuing to increase through 2030 [14].

2.2. Sit-Stand Desks: Efficacy and Usage

To mitigate the negative health effects of sedentary behavior, industries and researchers have developed various interventions, including treadmill desks, sit-stand desks, and active workstations [46, 47, 48]. Considering their convenience and lower energy demands, sit-stand desks and adjustable-height surfaces are widely recommended to facilitate alternating between sitting and standing throughout the workday [15, 16].

The adoption of sit-stand desks has been associated with multiple health benefits, including reduced sitting time [49], lower fatigue levels, and decreased musculoskeletal discomfort in the upper body [50, 51, 52]. Among school-aged children, regular use of sit-stand desks has also been associated with improvements in executive function and working memory skills [53]. Although the impact of sit-stand desks on productivity remains inconclusive [49], several studies suggest that their use can enhance workplace performance [54, 28, 50]. For instance, Garrett et al. found that call center employees using sit-stand desks processed 50% more calls than those using seated-only desks [28]. Similarly, Hedge et al. reported improvements in self-reported productivity among workers who used sit-stand desks [50].

Despite these potential benefits, sustaining regular use of sit-stand desks remains a challenge. While workers generally express positive attitudes toward sit-stand desks, actual usage tends to decline after an initial adaptation period [20]. A study indicated that approximately 60% of participants discontinued using sit-stand desks within a month of introduction [20]. Furthermore, the availability of shared standing desk areas has shown little to no impact on reducing sedentary behavior, with significant variability in individual usage patterns [19]. In another study, workers who did not receive ergonomic training on the benefits and proper use of sit-stand desks largely ignored them altogether [18].

While research emphasizes the importance of regular posture changes to maximize health benefits, the responsibility of developing this habit ultimately falls on the individual worker. Simply providing sit-stand desks may be insufficient for sustaining behavioral change, as they are often underutilized and easily forgotten in daily routines. However, the factors that encourage consistent and effective use of sit-stand desks—without negatively impacting productivity—remain poorly understood. Our long-term research goal is to address this gap by examining how knowledge workers integrate sit-stand desks into their daily routines and identifying strategies to promote healthier and more productive behaviors.

2.3. Notifications for Posture Switching

Frequent posture switching can benefit knowledge workers by promoting physical activity and reducing sedentary behavior. However, sustaining this habit requires effective nudges and attention-based interventions [55]. Due to the high cognitive demands of computing tasks and a lack of habit formation, users often forget to switch postures, leading to prolonged sitting.

Current approaches to facilitating postural changes primarily rely on notifications that remind workers to stand [23, 56, 21] or automated desk transitions at fixed intervals (e.g., standing for 10 minutes every hour or receiving hourly notifications on a wearable device) [22, 24, 57]. However, frequent interruptions can disrupt cognitive focus and reduce productivity [25, 58]. Specifically, notifications during computing tasks can cause users to lose track of their task goals [27]. A study found that users were most receptive to an autonomously moving standing desk, particularly when it transitioned between tasks, resulting in less perceived frustration and a preference for greater work efficiency [29]. Thus, leveraging "natural breakpoints"—such as task transitions or activity completions—has been shown to facilitate posture changes with minimal disruption [59, 60, 61].

To enhance engagement, health researchers are exploring just-in-time adaptive interventions, which deliver context-aware notifications to promote healthy behaviors while minimizing disruption [62]. For instance, Choi et al. developed the mobile intervention system "BeActive" to reduce sedentary behavior, demonstrating that intervention effectiveness depends on contextual factors [63]. Another critical area of research focuses on detecting when users are engaged in work or taking breaks, using machine learning algorithms to optimize notification timing [58, 64, 65, 66]. For example, the Attelia application analyzes application usage patterns and breakpoints to deliver notifications at optimal moments rather than at fixed intervals. However, these just-in-time adaptive interventions have not yet been applied or tested for sit-stand interventions. Given their potential, it is worth exploring whether adaptive interventions timed to natural breakpoints can effectively promote healthy behaviors while preserving productivity and focus.

2.4. Designing Intelligent, Context-Award Sit-Stand Interventions

Understanding how users interact with sit-stand desks provides valuable insights for designing intelligent, context-aware interventions. Research suggests that individuals develop distinct routines when using sit-stand desks, often based on task demands or time intervals. Chau et al. found that users prefer sitting for cognitively demanding tasks while opting to stand during less mentally intensive activities [23]. Similarly, Huysmans et al. observed that although individuals exhibit different sitting patterns, their usage remains consistent from day to day [67]. Other studies have highlighted that standing is often associated with increased creativity, whereas sitting is perceived to enhance task performance [68]. Additionally, transitions between sitting and standing are frequently regarded as natural work breaks, contributing to both mental and physical recovery throughout the workday [59, 61, 60].

Building on these insights, several researchers have explored automated sit-stand desks to understand how different automation strategies influence user experience. Lee et al. introduced a supervisory control system that automatically adjusts desk height while still allowing for user intervention. Their study, using a Wizard-of-Oz method, showed that participants felt more comfortable when the desk height was adjusted before tasks began [29]. Kim et al. investigated automated height adjustments through both empirical studies and surveys. In their empirical study, they tested a desk that automatically changed its height every 5 minutes. While this fully automated approach effectively encouraged posture changes, only half of the participants preferred it due to a perceived lack of control [24]. A follow-up survey with participants from the United States and India revealed that, overall, participants preferred manual or semi-autonomous desks over fully autonomous options [69]. Haliburton et al. developed a desk that rises after various patterns of inactivity and evaluated user preferences. Participants responded most positively when the desk rose after 3 minutes of inactivity, rather than at fixed intervals [57].

These studies highlight the importance of providing users with a sense of control over automated systems and the need for sit-stand desks to be context-aware and adaptable to individual work patterns. Building on this prior work, our ultimate goal is to develop intelligent sit-stand desk interventions that can leverage context awareness and personal preference to promote healthier posture habits while minimizing disruptions to productivity. Achieving this requires a comprehensive understanding of users' multidimensional contexts, including their work-related tasks, physical environment, and personal habits.

3. Methods

3.1. Participants

We recruited 10 knowledge workers (5 male, 5 female) whose primary work tasks involved computer-based activities. The mean age was 29.0 years (SD = 6.2), with an age range from 22 to 43. All participants were university graduate students who met the following criteria: 1) Age $\geq$ 18 years; 2) MacOS users; 3) Able to work in their office during the study; and 4) Permitted to install and run an external application on their work computers for data collection. The mean self-reported number of hours worked on computers per day was 7.0 hours (SD = 1.6). Prior experience with sit-stand desks or other height-adjustable surfaces was not a requirement for inclusion; however, eight participants had used such desks before the study. For logistical reasons, we limited recruitment to participants working in university buildings where we could manually deliver and set up the instrumented sit-stand desks. All participants provided written informed consent, and the study was conducted in accordance with the procedures approved by the Virginia Tech Institutional Review Board (IRB 23-179). Upon completing the three-week observation period, participants received a $75 gift card as compensation for their time and effort.

3.2. Developing Software and Hardware for Field Observations

3.2.1. Work Activity Monitoring using ScreenTracker

We developed ScreenTracker, a MacOS native application that runs in the background to track a computer's ongoing activities. ScreenTracker captures user interactions by monitoring metadata from the frontmost application's window every five seconds using AppleScript. Metadata in this context refers to digital data describing current computing activities, such as URLs and webpage titles for web browsers and document names and file paths for native applications (e.g., Microsoft Word). However, certain applications, such as Maps and Dictionary, provide no meaningful metadata beyond the application name itself. In these cases, we log only the application name (e.g., Map) while leaving the metadata field empty (see Appendix A for examples).

To address privacy concerns, we implemented several safeguards. All metadata was encrypted using the AES encryption algorithm [70], ensuring that unauthorized access would only reveal indecipherable strings without the correct decryption keys. Additionally, all collected data was stored locally on users' devices (e.g., textitUsers/[user name]/Documents/LoggingData/), eliminating the need for cloud-based storage and further enhancing privacy. Participants were explicitly informed at the beginning of the study that their data would be encrypted, alleviating concerns about potential privacy risks associated with ScreenTracker.

3.2.2. Sit-Stand Desk Height Monitoring

To accurately record sit-stand desk heights, we modified the control box of a commercial sit-stand desk (E5, FlexiSpot, California, USA), which offers a height range from 62.0 to 127.0 cm, to access data from its built-in encoder. This encoder tracks the positions of the servo motors and translates them into precise height measurements. The Raspberry Pi 3 Model B+ was connected to the desk's control box via an RJ-45 standard Ethernet connection, allowing it to read the height value displayed on the desk's LED panel. The Raspberry Pi autonomously monitored and logged desk height changes, along with corresponding timestamps, whenever an adjustment was made.

3.2.3. Pop-up Notifications

We implemented a pop-up notification system (Figure 1) that appeared every 30 minutes, regardless of the current height of the sit-stand desk. This notification prompted participants to log their willingness to switch to a standing posture using a 6-point Likert scale (1: Definitely Not to 6: Definitely). While not the primary focus of this study—and reserved for future analysis—these prompts captured participants' intentions regarding posture transitions. Designed to be minimally intrusive, the notification allowed for quick and seamless responses, minimizing disruption to participants' workflow and ensuring consistent data collection throughout the study.

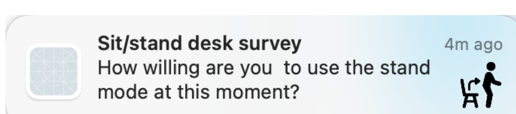

Figure 1: A pop-up notification system.

3.3. Field Data Collection Procedures

We conducted a three-week field observational study to capture participants' work, physical, and personal contexts in a real-world setting. The study followed a mixed-methods approach, incorporating surveys, automated field data collection, and post-study interviews. The procedure was divided into three key phases: the initial session, field observation, and post-study interview.

3.3.1. Initial Session

The study began with an in-person session to familiarize participants with the study requirements and ensure proper setup of the equipment and software. Participants first completed a pre-study survey, which collected demographic and background information, including age, gender, daily work hours, and prior experience with sit-stand desks. Each participant's existing desk was replaced with an instrumented sit-stand desk, equipped with a Raspberry Pi device for continuous height monitoring. This ensured ecological validity by allowing participants to continue working in their usual environments, eliminating external factors such as adapting to a new space (e.g., a research lab). Next, participants installed and configured ScreenTracker, a MacOS application designed to log computer activity metadata. Participants provided explicit consent for the collection of their daily computer interaction data.

To enhance awareness of the benefits of sit-stand desks, participants were required to complete an online Sit-Stand e-Guide training program (*sitstandguide.com.au*, [71]). This brief training educated them on the health advantages of alternating between sitting and standing. Importantly, participants were informed that sit-stand desk usage was entirely voluntary and could be based on their personal preferences and habits. There was no requirement to stand for a certain duration or frequency. For accurate data collection, participants were instructed to use ScreenTracker only while working at the sit-stand desk. This ensured that recorded computer activity corresponded to actual desk use, preventing instances where the desk was in standing mode but the participant was working elsewhere (e.g., at home).

3.3.2. Field Observation

Participants were observed over a three-week period (15 working days). The first week served as a warm-up session, allowing participants to familiarize themselves with using the sit-stand desks in their regular work environment. This adaptation period was particularly relevant for the two participants who had never used a sit-stand desk before. Prior research suggests that initial enthusiasm and comfort with new desks tend to peak within the first week before stabilizing over time [72]. To maintain a natural transition, no pop-up notifications were issued during this period, and the data collected was excluded from analysis.

The second and third weeks constituted the data collection period (10 working days). Participants continued using their sit-stand desks and computers as they had during the warm-up phase. However, during one of these two weeks, participants received pop-up notifications ("Notification" condition) prompting them to indicate their intention to stand. The sequence of the "Notification" week and "No-Notification" week was randomized across participants to control for potential order effects.

Throughout the study, participants were free to adjust their desk height and use their computers according to their personal preferences. This design ensured a naturalistic setting, allowing us to observe posture-switching behaviors with minimal external constraints.

3.3.3. Post-study Interview

Immediately following the three-week field observation, we conducted semi-structured interviews with each participant to gather qualitative insights into their experiences and future design considerations. The interview protocol (Appendix B) consisted of open-ended, semi-structured questions designed to explore key themes, including:

- Triggers and Goals: “What prompts you to switch postures?”
- Usage Experience: “What is your strategy or habit for switching postures while working?”
- Impact of Notifications: “How do you feel about receiving notifications?”
- Personal Preferences and Suggestions: “What improvements would you recommend for sit-stand desks and the computing ecosystem?”

All interviews were transcribed verbatim and manually reviewed by the first author to correct any errors. Following Clarke and Braun’s thematic analysis methodology [73], two investigators repeatedly read the corrected transcripts to develop a deep understanding of the dataset. In the initial coding phase, we generated 156 distinct codes. Through axial coding, these codes were refined—revised, merged, and stripped of redundancies—to identify the core themes emerging from the data. This structured process systematically captured participant experiences and insights. The final analysis organized 19 themes into five overarching categories of design considerations for enhancing sit-stand desks to support productivity and healthy behavior: (1) context awareness, (2) information, (3) notification, (4) self-tracking, and (5) environment.

3.4. Data Processing and Analysis

To analyze participants' computing activities, we processed the metadata collected by ScreenTracker and categorized them into distinct work activity types. We defined 13 computing activity categories based on a review of metadata from pilot studies and categories used in prior literature [74, 75]. These categories included: coding, design, reading, planning, browsing for work, writing, video meetings, email, messaging, shopping, social media, entertainment, and browsing for break.

Activity categories were further grouped into three major states based on the nature of the tasks, including "productive", "interactive", and "distracting", as described in Table 1. Productive work state was composed of focused tasks that contribute directly to work output (i.e., coding, design, reading, planning, browsing for work, and writing). Interactive work state was composed of communication-driven tasks requiring engagement with others (e.g., video meetings, email, messaging). Distracting state was composed of activities unrelated to work that may reduce productivity (i.e., shopping, social media, entertainment, and browsing for break).

To classify work activities, we used a pre-trained zero-shot text classification model, DistilBERT [76]. This approach enabled automated classification of metadata into predefined categories without the need for extensive manual labeling. We processed decrypted and de-identified metadata as input for the model. After initial classification, the second author conducted a manual screening step to correct potential misclassifications, ensuring high accuracy in the categorization process. This process allowed us to systematically translate raw application metadata into meaningful work activities and work states, as summarized in Table 1.

To examine whether certain work activities were more likely to be performed in a standing posture, we normalized the standing time by the total

Table 1: State-Activity descriptions with corresponding examples.

State	Activity	Description	Example Application
Productive	Coding	Writing instructions for a computer to follow	Xcode
	Design	Creating solutions for specific needs	Figma (Google Chrome)
	Reading	Reading work-related and professional contents	Zotero
	Planning	Outlining steps and strategies	Calendar
	Browsing For Work	Browsing internet for work-related contents	Google Chrome
	Writing	Writing work-related contents or professional papers	Google Docs (Google Chrome)
Interactive	Video Meetings	Meetings through online platform	Microsoft Teams
	Email	Communicating with others using electronic letters	Microsoft Outlook
	Messenger	Platform based communications and interactions	Slack
Distracting	Shopping	Visiting web with intention of shopping	Amazon (Google Chrome)
	Social Media	Accessing social media through web	LinkedIn (Google Chrome)
	Entertainment	Using application to fulfill one's interest	Spotify
	Browsing For Break	Browsing internet for non work-related contents	Breaking News (Google Chrome)

activity time for each workday and participant (referred to as "Standing %"). This normalization was necessary because participants had varying working hours each day, and using raw standing time could obscure proportional differences—longer durations for certain activities might simply reflect longer overall engagement rather than a true preference for standing.

To further assess whether posture usage varied by work state, we created a binary outcome variable from the total standing time recorded for each work activity per day. Standing time greater than 1 minute was coded as "1" (standing occurred), and time less than 1 minute was coded as "0" (no meaningful standing). We then used nominal logistic regression to test the effects of work state and notification condition on the likelihood of standing. A chi-square test was also performed to assess the association between posture switching and task type. JMP (v.18) software was used to conduct the analysis, and statistical significance was concluded when $p < .05$.

4. Results

The mean logged work hours from each participant per each day was 3.8 hours (SD = 1.5), during the field observation except for the warm-up session. Sit-stand desks were used in sitting mode with a mean of 2.8 hours (SD = 1.1), and in standing mode of 1.0 hours (SD = 1.0).

4.1. RQ1: Which work activities do users tend to perform while standing versus sitting?

Participants exhibited distinct postural patterns depending on the type of work activity. As shown in Figure 2 (top), the mean daily standing time was highest during coding (24.5 minutes), followed by design tasks (16.6 minutes).

In general, participants spent more time standing during productive activities than during interactive or distracting ones.

To further explore standing behavior across activities, Figure 2 (bottom) presents the mean daily normalized standing ratio (i.e., proportion of time spent standing per activity). Interestingly, entertainment activities—classified under distracting work—had the highest proportion of standing time (32.9%), though this difference was not statistically significant.

At the broader work state level, we observed significant differences in postural behaviors based on work state and notification condition (Table 2). Specifically, participants were more likely to perform productive work in a standing posture compared to distracting work (Odds Ratio [OR] = 2.75). Similarly, interactive work was also more likely to be performed while standing compared to distracting work (OR = 2.27).

Table 2: Results of nominal logistic regression for standing posture.

Variable	**Category**	**Reference Category**	**P-value**	**Odds Ratio (OR)**	**95% CI for OR**
Work state	Productive	Distracting	$<.001$	2.75	[1.81, 4.28]
	Interactive	Distracting	.001	2.27	[1.42, 3.69]
	Productive	Interactive	.266	1.21	[0.87, 1.70]
Notification	Notification	No notification	.001	1.76	[1.26, 2.49]

Based on our results, it seems that using the standing mode was not necessarily associated with getting distracted or doing routine tasks. Instead, participants actively used it when they worked on cognitively demanding tasks. Semi-structured interview results supported the behavioral trends observed in the quantitative data. Most participants (9 out of 10) reported developing a sense of which tasks felt more appropriate for standing mode. When asked about preferred tasks while standing, responses varied: writing and reading were each preferred by 4 out of 10 participants. These preferences appeared to be influenced by both task type and individual comfort. Several participants noted that tasks requiring focus or concentration were better suited to standing, aligning with patterns observed in the statistical analysis.

For example, P4 shared:

> "*I do enjoy standing ... [when] I'm just reading a document, or doing any work that doesn't [require] rigorous focus. [...] I think I've used [the standing desk] enough times to know that there are activities I like to do while standing, and I feel more focused while*

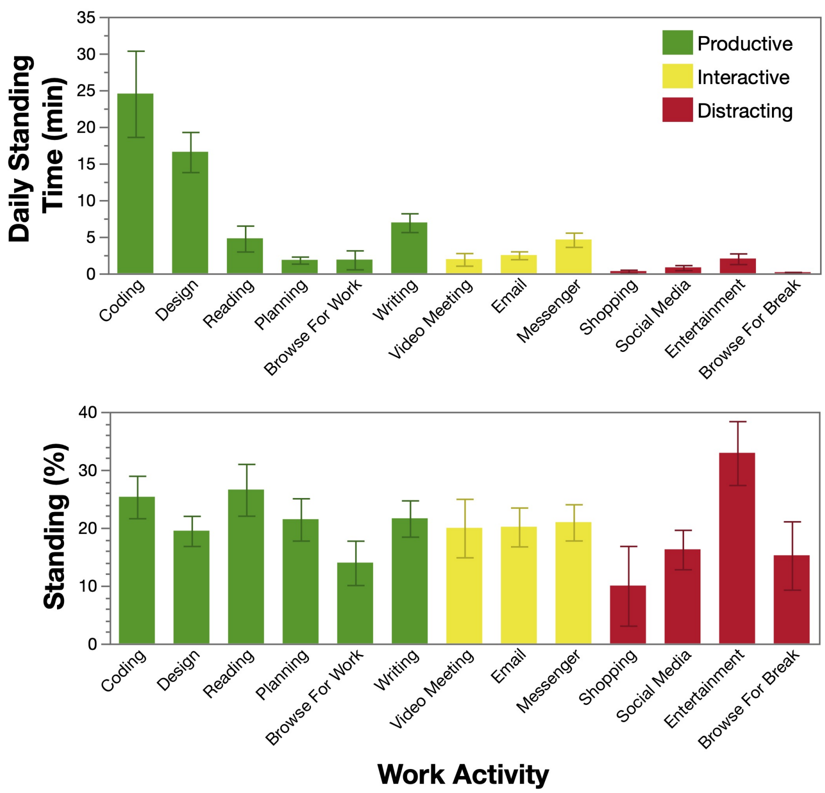

Figure 2: Mean daily standing time (min) and mean proportion of total standing time (%) for each activity type per participant work day, stratified by work state. Error bars represent standard errors.

standing. Such as writing a document, coding, or debugging— things like that." (P4)

Conversely, many participants also identified tasks they found less suitable for standing. Some reported that typing-intensive activities like writing or coding were physically uncomfortable while standing. Others expressed hesitation to use standing mode during socially interactive tasks, such as video meetings, citing feelings of awkwardness. These specific interview responses appear to diverge from our quantitative findings, where productive and interactive work states were more frequently performed while standing compared to distracting work. This mismatch may reflect individual variation in comfort, context, or task-specific ergonomic needs not captured in aggregate behavioral trends.

However, participants' preferences did not always constrain their behavior. While they expressed liking certain postures for specific tasks, they also reported adapting their activities in response to physical cues or discomfort. In some cases, posture changes triggered intentional task switching to better match the new physical state. As P5 explained:

> "*If I feel a little bit uncomfortable. I might change my task. So if I am typing something and I don't want to sit anymore, then I might change my task to reading and stand for a while.*" (P5)

These cases highlight that participants gradually developed strategies to combine posture switching with their computing tasks, based on personal preferences.

4.2. RQ2: Do posture switches coincide with transitions in work activity, and could these moments serve as appropriate opportunities for intervention?

To examine whether posture transitions naturally prompt a shift in task focus, we analyzed participants' work activities and work states one minute before and after transitions from sitting to standing. Across all participants, there were a total of 172 sitting-to-standing posture transitions. Figure 3 presents confusion matrices showing the counts of transitions between work activities (left) and work states (right) surrounding these posture changes. Diagonal cells represent instances where participants continued the same type of activity or work state before and after the posture transition, while off-diagonal cells indicate a change in task. For example, there were seven instances where participants were coding while seated and switched to writing after standing (i.e., the value in the first row and third column).

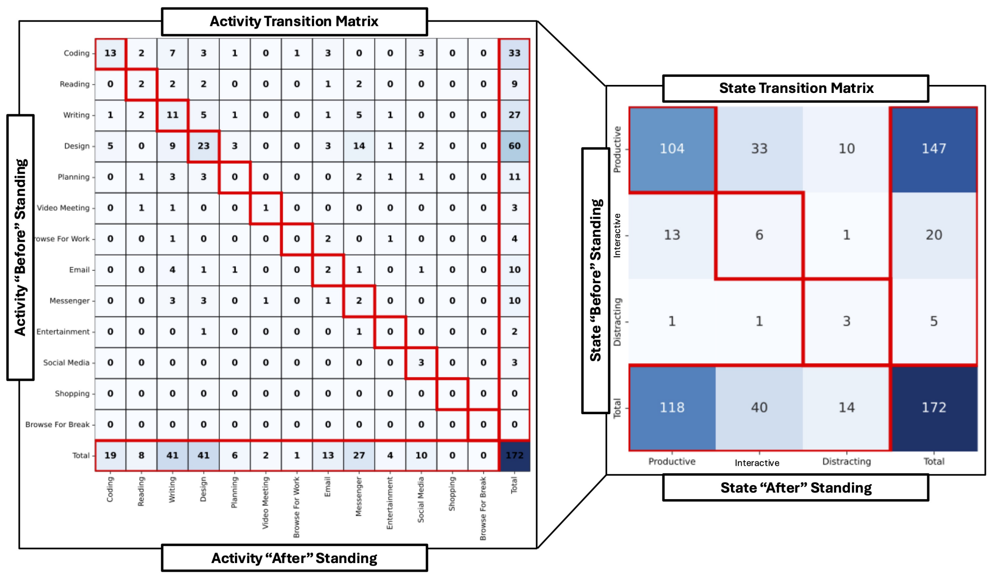

Figure 3: Confusion matrix showing the activities (left) and work states (right) performed before and after the posture transition (sitting to standing). A diagonal line represents no switch in the types of work activities or work states.

Due to sparse cell counts in the activity-level data, statistical analysis focused on work states. A Chi-square test revealed significant differences in work state transition patterns [$\chi^2(4,\ 172) = 19.39$, $p < .001$]. Post hoc comparisons showed that participants were more likely to maintain a productive state before and after standing, rather than switch to a distracting state [$\chi^2 = 76.17$, $p < .001$]. Similarly, participants tended to maintain interactive work states rather than shift to distracting states [$\chi^2 = 42.07$, $p < .001$]. Finally, transitions from interactive to productive work were significantly less frequent than maintaining a productive state across the posture change [$\chi^2 = 47.42$, $p < .001$].

Interview results both reinforced and elaborated on these observations. Most participants (8 out of 10) used posture changes to regain focus rather than to transition to a different work state. For example, P3 explained how standing helped improve concentration:

> "*Sometimes when I feel sleepy and cannot focus on the papers or something I'm reading, I change [my] posture and stand up.*" (P3)

Several participants also mentioned that using sit-stand desks to alternate postures helped alleviate boredom during tasks. P6 noted that standing offered a "fresh perspective" or helped break through creative blocks:

> "*Switching my posture also helped me switch my mind. It helps clean up the messy parts in my mind.*" (P6)

This suggests that participants strategically stood to restore focus during cognitively demanding tasks, aligning with our quantitative finding that they typically remained in a productive state after standing rather than switching to a different work state. One participant noted a perceived boost in productivity from alternating between sitting and standing, as sitting was "*too comfortable to focus*" (P2).

Interestingly, most participants (9 out of 10) reported choosing to stand when feeling tired or low on energy—a counterintuitive choice given that standing can require more physical effort and may cause discomfort. However, many believed standing helped them overcome various kinds of mental discomforts: feelings of fatigue, boredom, or writer's block. For example, P9 stated:

> "*Whenever I was feeling tired or something, I switched my position, and that helped me to get a boost of sometimes energy or like at least concentration.*" (P9)

Overall, participants described posture switching as providing both physical and mental refreshment without leaving their desks.

4.3. RQ3: How do users' behaviors change in response to posture-related notifications?

To examine whether the presence of pop-up notifications influenced participants' sedentary behavior, we compared the standing time between the two conditions—no notification and with notification (Figure 4). On average, participants stood longer when prompted with a pop-up notification (daily mean standing time = 72.1 minutes) compared to when no notification was shown (46.2 minutes), across all work states. This observation was supported by results from nominal logistic regression (Table 2), which indicated that participants were significantly more likely to stand when they received pop-up notifications (Odds Ratio [OR] = 1.76).

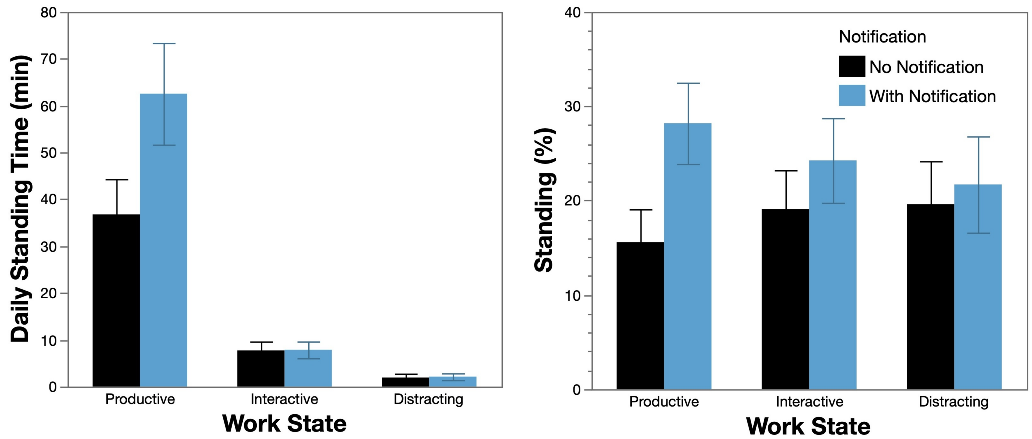

Figure 4: Mean daily standing time (min) and mean proportion of total standing time (%) by work state and notification condition.

Participants generally acknowledged that the notifications helped remind them to switch postures, especially when they lost track of time spent sitting:

> *"Even though I wasn't able to look at my watch, I could see something from my computer saying like, hey, you might want to stand up now and then. Those notifications did influence me to stand up. Sometimes, when I saw them, even though maybe I would sit down 10 to 15 minutes later, I would still at least initially stand up from those notifications."* (P4)

> *"The reminders from the application sometimes gave me the sense that, okay, do I want to stand right now or not? It was like a nudge to me."* (P1)

A few participants (2 out of 10) specifically noted that the regularity of notifications increased their awareness of how long they had been sitting. However, except for those two participants, the majority (8 out of 10) reported that the timing often felt disruptive. A common complaint was that notifications appeared during moments requiring concentration or during meetings:

> *"Of course, sometimes, when I focus on coding or I'm doing an interview, the notification would disturb me, and I'm going to ignore it. So, that is not a proper time. A lot of times, I just ignore it because it's not the right time."* (P3)

> *"Sometimes I have meetings, and the notification pops up even though I'm not in a situation where I can stand up. So, during a two-hour meeting, that notification might pop up quite a few times, which can be annoying."* (P6)

Most participants expressed frustration when notifications interrupted their focus or social interactions during remote meetings. One participant also described how the notifications not only disrupted concentration but sometimes led to distraction by shifting attention to unrelated tasks:

> *"You're trying to get something done, and you're super focused. So because that [the notification] makes you completely get out of focus... So you start using your phone or doing something else."* (P9)

Despite increasing standing time and raising awareness, posture-related notifications were often perceived as disruptive—particularly during focused work or meetings—highlighting the trade-off between behavioral nudging and productivity.

4.4. RQ4: What design considerations can enhance the effectiveness of sit-stand desks in promoting productivity and healthy behaviors?

Through semi-structured interviews, participants shared a variety of ideas and suggestions for improving future intelligent sit-stand desks. Thematic analysis of the interview data revealed five key design categories, each encompassing specific second-level themes that can inform future development. These categories, along with their descriptions and illustrative examples, are summarized in Table 3.

Table 3: Summary of user-informed design considerations for improving sit-stand desks to support productivity and healthy behaviors.

Category	**Factor**	**Description**	**Example**
Context Awareness	User's Schedule	Adapt prompts based on calendar events to avoid interruptions.	Skip notifications during scheduled meetings.
	Work Type	Tailor posture suggestions to match the nature of the current task.	Prompt standing during focused, productive work.
	Time of Day	Schedule prompts based on common daily routines.	Send reminders after lunch or mid-afternoon.
	Elapsed Sitting Time	Monitor cumulative sitting time and issue reminders accordingly.	Notify after sitting continuously for 2 hours.
	User Presence Detection	Detect presence to avoid unnecessary desk movement and resume prompting after breaks.	Switch to standing mode when the user returns.
	Physical Condition	Adjust desk height based on the user's posture or ergonomic needs.	Raise desk if the monitor is below eye level.
	Sensing Integration	Incorporate data from external devices to inform posture suggestions.	Sync with a smartwatch or fitness tracker.
Information	Productivity Benefits	Explain how posture changes can improve cognitive performance.	"Standing can help you focus better."
	Health Benefits	Emphasize physical benefits of reducing sedentary time.	"Standing more may lower your cardiovascular risk."
Notification	Avoid Interrupting Focused Work	Delay prompts during deep concentration or communication tasks.	Don't notify while coding or during meetings.
	Notification Regularity	Adjust reminder frequency based on user preferences and patterns.	Customize intervals to fit user behavior.
	Notification Salience	Make prompts noticeable without being disruptive.	Use soft sounds or subtle animations.
	Short Tasks for Standing	Suggest brief, suitable tasks when prompting posture change.	Recommend standing when replying to emails.
	Notification Integration	Deliver notifications across multiple devices for convenience.	Send reminders to a smartwatch or phone.
Self-tracking	Personal Goals	Allow users to set and monitor custom standing targets.	Track progress toward a 2-hour standing goal.
	Visual Tracking	Provide visual feedback on daily posture habits.	Show charts of sitting vs. standing
Environment	Social Context	Consider nearby people and interactions when prompting.	Avoid alerts during virtual or face-to-face meetings.
	Spatial Awareness	Factor in shared workspace constraints before suggesting posture switches.	Avoid prompting when nearby coworkers are standing.

5. Discussion

In this section, we synthesize findings from our observational and semi-structured interview studies on knowledge workers' behavior patterns to propose design considerations for optimizing sit-stand desk usage and explore strategies for encouraging posture switching from a productivity-oriented perspective.

5.1. RQ1: Standing for Productive and Interactive Work

Our observational findings suggest that participants were more likely to stand while engaged in productive or interactive tasks, rather than during distracting activities. While our observational study cannot determine causality—i.e., whether standing directly improved focus and productivity—this pattern is consistent with prior research examining the relationship between posture and cognitive performance. For example, Finch et al. [68] found that standing did not significantly affect reading comprehension or creativity, but it did enhance task engagement by increasing alertness. Similarly, Kar et al. [77] reported that standing during short-term typing tasks reduced errors without impacting typing speed. Combined with our interview data, these findings suggest that standing may support cognitive functions such as attention and engagement—particularly when prompted or used in ways that do not disrupt ongoing tasks.

5.2. RQ2: Posture Shifts to Maintain, Not Change, Work States

Interestingly, our data revealed that posture transitions did not typically coincide with task transitions. Participants often maintained their productive or interactive work states before and after standing, which contrasts with findings from prior studies. For example, Robertson et al. [78] reported that posture changes frequently aligned with task transitions, creating natural opportunities to interrupt prolonged sitting or standing. Similarly, Lee et al. [29] found that participants preferred adjusting desk height between task changes, as it minimized disruption and discomfort. In contrast, our observations showed that posture changes often preserved the same type of work state (e.g., productive to productive; interactive to interactive). This suggests that participants may have used posture changes not as a response to task boundaries, but rather as a cognitive refresh mechanism—a perspective also reflected in several interview responses.

5.3. RQ3: Encouraging Standing Time Without Disrupting Work

Frequent notifications can serve as external interruptions, potentially disrupting knowledge workers' focus and workflow [79]. However, our interview data revealed that participants generally perceived well-timed notifications as beneficial. These reminders not only encouraged healthier behaviors—such as posture switching, as supported by our observational findings—but also helped participants refocus on their tasks.

When appropriately timed, notifications may serve as an effective tool to reduce sedentary behavior without significantly interrupting task performance. However, our study could not determine the optimal timing for such interventions. Although many participants expressed a preference for receiving reminders during task transitions, our observational data did not support this: participants typically maintained the same work state before and after standing, suggesting that posture changes were not tied to task boundaries.

This discrepancy points to a key design challenge—how to identify intervention moments that maximize physical benefits while minimizing cognitive disruption. Future systems should explore real-time sensing methods to detect natural cognitive or physical breakpoints in workers' routines. For example, physiological indicators of vigilance loss [80] or patterns in eye movements [81] could signal waning attention, providing an opportunity for posture change as a way to regain focus.

Since our findings suggest that task transitions are not a reliable trigger for intervention, monitoring subtle signs of cognitive fatigue or disengagement—such as a decline in deep focus—may offer a more effective and personalized strategy for encouraging posture switching.

5.4. RQ4: Design Considerations toward Intelligent Sit-Stand Intervention

Considering Multi-Faceted Nature of Contextual Information: One key limitation of current sit-stand desks, as noted by participants, is their lack of contextual awareness. Users expressed a desire for systems that could dynamically suggest posture changes or automate desk height adjustments with minimal manual input. This highlights the need for intelligent algorithms that account not only for users' computer-based activities but also for their physical state and personal routines.

To effectively support behavior change, it is essential to recognize that context is not static or singular. Instead, it comprises a broad range of dynamic factors—including the physical environment, bodily conditions, ongoing tasks, and individual preferences—all of which influence how knowledge workers engage with sit-stand desks.

Prior research supports this perspective. For instance, mobile activity-sensing systems have shown that context-aware self-tracking can increase physical activity [82]. Similarly, studies on adaptive systems have emphasized the value of leveraging diverse contextual inputs to personalize user experiences [31, 83, 84, 85]. Feng et al.[86] demonstrated how mobile interfaces can adapt to user behavior and past patterns, while Mayer et al.[87] found that a user's level of engagement in a task predicts their willingness to change behavior—consistent with our findings that participants were less receptive to posture-switching prompts during high-focus tasks.

Our study reinforces the importance of integrating diverse contextual cues to support healthy and productive behaviors. A major design challenge remains: determining how to prioritize and personalize these cues for each user. Future research should explore real-time, context-aware adaptations that tailor prompts based on individual needs, enhancing both user engagement and outcomes related to health and productivity.

Users Are Often Unaware of Their Own Behavior: A key finding from our study is that users frequently lack awareness of their own posture and behavior patterns during work. Research suggests that only 10–15% of people are truly self-aware [88], and this extends to posture awareness. Achieving health goals requires more than simply tracking how long one has been sitting—it also involves understanding how long to stand to gain optimal benefits.

While prior research shows that increased self-awareness can encourage positive behavior change [89], ergonomic awareness alone does not reliably reduce sedentary time [90]. Our findings echo this: even participants who reported being mindful of their postures still struggled to balance sitting and standing without external prompts.

To address this gap, some have proposed automated interventions. For example, Kim et al. [24] designed a desk that adjusts height at pre-set intervals. Although this ensures users alternate postures, our participants expressed mixed opinions about such automation. They valued the potential for consistency but also emphasized the importance of autonomy—wanting to be notified in advance and given the option to override automatic changes based on situational needs.

We also observed a tension between ingrained habits and aspirations for healthier behavior. Many users defaulted to sitting out of comfort or routine, illustrating how difficult it is to sustain posture switching through habits alone. Without real-time feedback or personalized support, users often reverted to behaviors misaligned with their health or productivity goals.

Personalization is essential in overcoming this challenge. Prior work shows that tailored feedback enhances engagement and supports behavior change [91, 92]. Sit-stand desks should therefore be equipped with intelligent systems that not only increase awareness but also provide context-sensitive, personalized prompts to guide behavior.

In summary, habits alone are insufficient for sustained posture management. Future systems must empower users through real-time feedback, intelligent automation, and personalization to better align behavior with long-term health and productivity goals.

6. Limitations and Future Work

While this study provides valuable insights into the design of intelligent sit-stand desks that support healthy and productive behaviors, several limitations must be acknowledged. First, the relatively small and homogenous participant pool limits the generalizability of our findings. Although graduate students represent a relevant subset of knowledge workers, future work should expand the participant base to include individuals from more diverse professional backgrounds, demographics, and work environments. This would allow for a broader understanding of posture-switching behaviors and contextual needs across different user groups.

Second, the scope of context sensing was limited. Our use of ScreenTracker allowed us to log computer-based activities, but it did not account for off-screen behaviors or environmental factors. Consequently, we could not fully capture the complex interplay between digital and physical distractions, users' physical states (e.g., fatigue, discomfort), or emotional conditions (e.g., stress, mood). Future systems should aim to integrate a richer set of contextual signals—such as ambient environment, body metrics, or self-reported affect—to provide more accurate and adaptive support for posture switching.

Third, our analysis focused primarily on transitions from sitting to standing, without examining reverse transitions or other posture variations. While this focus enabled a deep dive into standing behaviors, it does not capture the full range of posture dynamics in naturalistic settings. Future studies should investigate bidirectional transitions and other micro-postural adjustments (e.g., leaning, walking breaks) to better understand their impact on health and productivity.

Together, these limitations point to several promising directions for future research: expanding participant diversity, enriching multimodal contextual sensing, and broadening the scope of posture behavior analysis. Addressing these areas can inform the design of more intelligent, personalized, and context-aware sit-stand desk systems that better align with users' health and work needs.

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Appendix A. Tracked Metadata Overview

We collected participants' computer activity metadata using ScreenTracker, which included application names and two relevant types of metadata for each. Applications not listed in the table (e.g., Slack, Zotero, Dictionary, Map) had their usage tracked, but no associated metadata were recorded.

Table A.4: Collected participants' computer activity metadata using ScreenTracker.

Application Name	1st Metadata	2nd Metadata
Safari	Website URL	Website Title
Google Chrome	Website URL	Website Title
Microsoft Excel	Local File Path	File Name
Microsoft Word	Local File Path	File Name
Microsoft PowerPoint	Local File Path	File Name
Acrobat Reader	Local File Path	File Name
Preview	Local File Path	File Name
Xcode	Local File Path	File Name
Eclipse	Local File Path	File Name
TextEdit	Local File Path	File Name
Pages	Local File Path	File Name
Numbers	Local File Path	File Name
Keynote	Local File Path	File Name
Finder	Local Folder Path	Folder Name

Appendix B. Semi-Structured Interview Questions

1. Have you used sit-stand desks or similar equipment before this study? If so, for how long and in what context (e.g., work, study)?
2. What are your general thoughts and feelings about using a sit-stand desk for work or study?
3. What is your strategy for switching postures while working or studying? Do you have any specific habits or routines?
4. During the study, how did you feel about receiving notifications to remind you to switch postures? Did you find them helpful or disruptive?
5. What motivates you to switch postures? Conversely, what factors make it difficult for you to change your current posture?
6. Before the study, what were your opinions on regularly switching postures?
7. After the study, did you notice any changes in your behavior or habits when using the sit-stand desk?
8. Do you have any suggestions for making sit-stand desks smarter, more helpful, or user-friendly?