The Haunted Desk: Exploring Non-Volitional Behavior Change with Everyday Robotics

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Figure 1: A user stands-up as he follows the autonomously rising desk from their ergonomic sitting desk height (left) to their ergonomic standing desk height in (right)

ABSTRACT

We introduce and explore the concept of non-volitional behavior change, a novel category of behavior change interventions, and apply it in the context of promoting healthy behaviors through an automated sit-stand desk. While routine use of sit-stand desks can increase health outcomes, compliance decreases quickly and behavioral nudges tend to be dismissed. To address this issue, we introduce robotic furniture that moves on its own to promote healthy movement. In an in-person preliminary study, we explored users' impressions of an autonomous sit-stand desk prototype that changes position at regular pre-set time intervals while participants complete multiple tasks. While in-the-moment self-reported ratings were similar between the autonomous and manual desks, we observed several bi-modal distributions in user's retrospective comparisons and their qualitative responses. Findings suggest about half were receptive to using an autonomous sit-stand desk, while the remaining preferred to retain some level of control.

CCS CONCEPTS

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

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KEYWORDS

Non-Volitional Behavior Change; Robotic Furniture; Anti-Sedentary Desk; Autonomous Desk

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1 INTRODUCTION

In this paper, we introduce the concept of non-volitional behavior change which we define as a infrastructure-mediated intervention to enforce a change in behavior such as activity and posture. In a broader context, it can be defined as a compulsory change in behavior in response to a change in the environment.

The Haunted Desk is an instance of creating non-volitional behavior change using robotic technology to provide health benefits that mitigate the dangers of prolonged sedentary behaviors, which are associated with poor overall health [14]. In theory, even conventional sit-stand desks help to facilitate reductions in sedentary time and potentially mitigate health risk factors [8]. However, about one-third of sit-stand desk owners use the sit-stand functionality less than once a month [15]. An online survey of 1098 owners found that the reason users did not use this functionality was that they simply “do not bother” to do so, despite awareness of the health implications with sitting too long [21] and a desire for a healthier lifestyle [3]. To increase adherence to consistent use of sit-stand desks, we propose the Haunted Desk that automatically controls the transitions between sitting and standing, alleviating users from the burden of decision making while promoting healthy movements across the workday.

Through an iterative design process, we developed an automated sit-stand desk that is low-cost and includes an anti-pinch safety function, micro height adjustment options, and a simple haptic movement notification. Unlike past work on comfort-focused and task-dependent autonomous sit-stand desks [10], we implement a task-independent timer-based solution that prioritizes a health-focused actuation schedule. Using this autonomous sit-stand desk, we gathered preliminary user impressions, both in-the-moment (experience) and retrospective, and compared them against those for a manual desk. The study results demonstrate that while the in-the-moment ratings were similar between the autonomous and manual desks, we observed bi-modal distributions in user’s retrospective comparisons. Qualitative data also shows that users were split in their preference between the two desks with sense of control consistently cited as an important aspect regardless their choice.

2 BACKGROUND

2.1 Nudging with Robotic Furniture

Past work has explored the use of “nudges” or indirect suggestions by technology (e.g., push notifications, default options) to facilitate behavior change [2, 16]. We distinguish a nudge from non-volitional behavior change as a suggestion that can be ignored if desired, whereas the latter constrains users by automatically driving them to engage in the behavior change. Nudges are thought to lessen the burden of decision making and increase the likelihood of the user completing a desirable or sufficiently easy task [16]. For example, previous work has found that merely setting the default desk height of a sit-stand desk to be at standing level at the start of the work day increased standing work rates for employees [20]. The reason for this might be that people have a strong tendency to go along with default options because proactive change of the desk height demands additional cognitive load [16]. It is therefore unsurprising that technology is shifting toward increasing levels of autonomous delegation and supervision [12].

Building on this prior work, robotic furniture is an emerging research area. Several designs focus on modifying behaviors at home or in the office. Prior research at home describes a robotic box for encouraging toy collection by children [6] and trash cans that incentivize trash collection [22]. More directly related to our work, Breazeal et al. explored adaptive screen heights to correct posture and found that most participants changed their posture to match the screen’s position resulting in reports of being more comfortable and extending the time they worked on cognitive tasks [1]. We propose a robotic desk that promotes anti-sedentary lifestyle by compelling users to alternate position at an optimal frequency.

2.2 Sedentary Lifestyles

Sedentary lifestyles are becoming increasingly common during the technology age [18, 19]. Globally, 41.5% of our populations worldwide spends four hours or more sitting per day across both high and low-income populations [7]. With humans engaging in increasingly more sedentary lifestyles, various studies have been conducted to assess the damage such sedentary behavior can induce. For instance, prior work found thatsuch sedentary lifestyles are associated with poor overall health and increased mortality risk [9, 14]. Interrupting this sedentary time with frequent light movement has been found to be associated with increased health benefits [4, 8]. Recent research shows that movement every 30 minutes may help people live longer [4, 5]. In this paper, we propose the use of autonomous desks to break long sedentary periods into shorter intervals to propel users toward healthy, anti-sedentary behaviors using a non-volitional approach to behavior change.

3 AUTONOMOUS SIT-STAND DESK DESIGN

An autonomous robotic sit-stand desk, or "Haunted Desk", has the potential to improve adherence to anti-sedentary lifestyle in office environments through non-volitional behavior change. In order to understand how people perceive and react to such systems, we employed a user-centered approach where we developed a prototype of an affordable electronic module that can be used directly in a commercial sit-stand desk. We conducted short qualitative studies to iterate on the design and establish which were the minimum set of sensors, actuators, and features required to deliver a fully autonomous experience for sit-stand desk users.

The first round of feedback centered around the usability of the desk in terms of noise and speed. As these aspects were limitations of the commercial sit-stand desk itself, we changed our first off-the-shelf base desk to a faster and quieter model—–specifically the Conset 501-27. With the second prototype, participants voiced concerns about the safety of working with autonomous desks in that they felt that the desk might lower onto their laps. To alleviate such concerns, we implemented an anti-pinch safety feature using a combination of an ultrasonic distance sensor to detect objects below the desk and a thermal imaging device to detect users. Finally, the last key component to designing the desks was optimizing its ergonometric capabilities. To do so, we used an ergonomic design tailored to each user by entering the participants’ body measurements such as height into an ergonomic desk configuration calculator to set the desks sitting and standing heights [17]. Additionally, we implemented users’ suggestions about adding a micro height adjustment feature to improve user comfort and allow people to quickly modify the desk height for their own comfort.

Our final prototype (Figure 2) is composed of: an electric height adjustable desk (Conset 501-27), an ultrasonic distance sensor (HC-SR04) to control the height of the desk and prevent pinching, a thermal camera (MLX90640 55O) to detect presence of the user, and a microprocessor (Arduino Nano) to manage all of the above components. The entire electric module costs approximately $80 (fabrication cost per single unit) which could be further reduced when mass-manufactured. To allow users to perform fine adjustments, there are two buttons (up and down) on the right side of the desk that come standard. However, we modified interactions

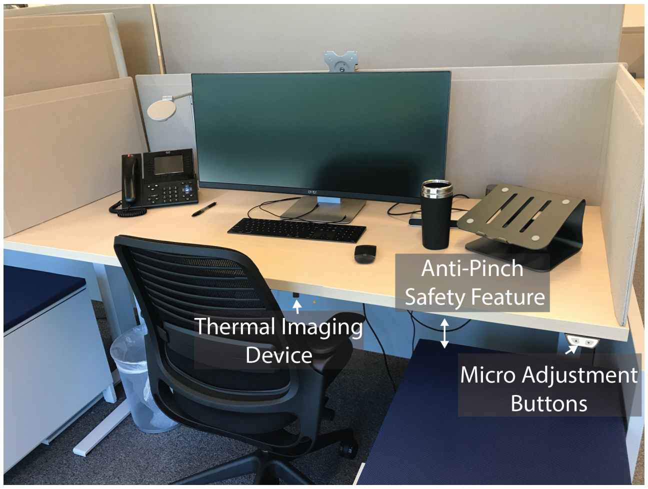


Figure 2: A commercial manual sit-stand desk was modified to change height automatically at preset intervals with an anti-pinch system for safety and a thermal camera to detect user presence and movement.

Table 1: Means and standard deviations of the ratings of both desks in-the-moment and post-study reflective comparison.

Measure	*In-the-moment* ratings for Autonomous Desk	*In-the-moment* ratings for Manual Desk	*Reflective comparison* ratings (+: manual,-: autonomous)
Likeability	5.0 (1.1)	5.2 (1.1)	+0.2 (1.9)
Safety	5.4 (1.0)	5.9 (0.6)	+1.0 (1.1)
Productivity	5.0 (1.0)	5.0 (1.2)	+0.5 (1.4)
Stress	2.4 (1.0)	2.6 (1.3)	-0.5 (1.5)
Recommend	4.9 (1.3)	5.1 (1.1)	+0.4 (1.6)

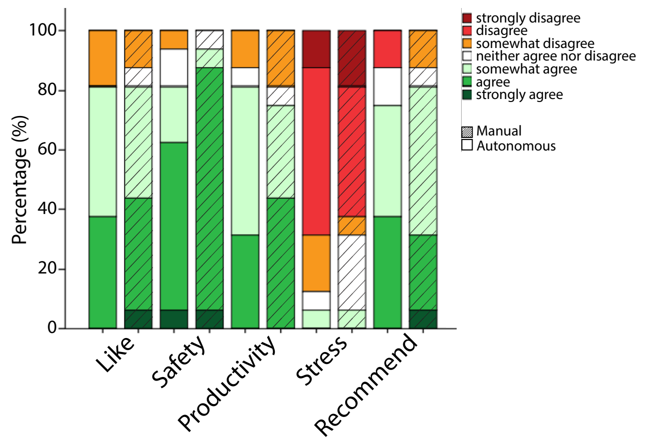


Figure 3: *In-the-moment* ratings for both desks.

with these buttons such that a constant press of the button raises or lowers the desk until released while a rapid double press will raise or lower the desk to the preset standing or sitting height.

4 PRELIMINARY IN-PERSON STUDY

To help understand the important aspects of non-volitional behavior change via an autonomous sit-stand desk, we conducted a preliminary in-person mixed methods within-subject study. After performing three different tasks and experiencing both the manual and autonomous desks in a counterbalanced order, participants described their reactions to using these desks and provided feedback on how the two conditions could be further improved.

4.1 Study Procedure

We recruited 16 participants (8 female, 8 male, 0 non-binary) from our institution via university mailing lists. The average age of the participants was 33 years old (*SD*=12). In terms of race, participants identified themselves as white (9/16), Asian (6/16), and preferred not to identify (1/16). Most participants (10/16) reported that their job required them to sit for long hours daily.

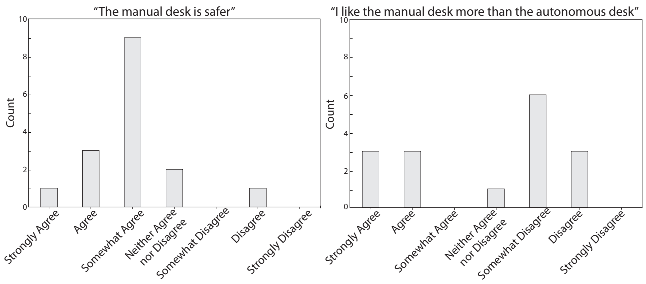
At the start of each study session, participants entered a simulated office room with two desks. The room was distraction-free with no window access to control for environment influences (e.g., lighting conditions, HVAC). The desk heights were pre-adjusted by the experimenter based on each participant's height using an ergonomic desk configuration calculator [17]. Both desks were at the sitting condition at the start. The presentation of stimuli was counterbalanced where half of the participants were randomized to experience the manual desk first and then the autonomous desk, and the other half experienced the desks in the opposite order. At each desk, participants completed video comprehension, reading, and typing tasks on a laptop for 15 minutes and provided in-the-moment ratings of each desk on the following aspects on a 7-point Likert scale: likeability, safety, productivity, stress, and how recommendable it is. Immediately after completing the study, they completed a brief survey retroactively comparing the two desks on the same aspects mentioned above on a 7-point Likert scale, and answered questions about their impressions of the two desks during a brief follow-up semi-structured brief interview.

The autonomous desk, as described in Section 3 and shown in Figure 2, was pre-set to change height automatically every 5 minutes. The manual desk had an identical interface and button controls as the autonomous desk, but it did not move automatically.

4.2 Results

With the manual desk, participants changed heights on average 0.63 times with SD = 0.72 during the study, while the autonomous desk was programmed to change heights twice for each participant.

4.2.1 Self-Reported Ratings. The autonomous and manual desks were rated similarly except for safety as shown in Table. 1. The distributions of the in-the-moment ratings for both desks were also similar as shown in Figure 3. However, when looking at post-study reflective comparison ratings, we observed bi-modal distributions for some variables such as likeability, stress, and likelihood of recommendation to others, and uni-modal distributions for other variables such as safety and productivity as shown in Figures 4. This discrepancy between in-the-moment and post-study reflective comparison ratings suggest that user's experiential impressions and retrospective impressions may not always be aligned and warrant further investigation.



(a) Distribution for Safety **(b) Distribution for Likeability**

Figure 4: *Reflective comparison* ratings for safety and productivity had uni-modal distributions as shown in (a) but *reflective comparison* ratings for likeability, stress, and recommend had bi-modal distributions as shown in (b).

4.2.2 Qualitative Impression. Participants were split in their preference for the manual and autonomous desks. About half of participants (9/16) preferred the autonomous desk because of its non-volitional height changes that forced them to alternate between sitting and standing as a means of benefiting their health. For instance, P16 said that "*... I know I need to get up and down, but it is so easy to forget. Being "forced" to do so is better for my health...*" while P9 expressed a similar desire toward "*wanting to move around to keep fit but I usually can't do that. The automatic one forces me to move.*" In terms of suggestions for improvement, seven participants wished there were a "snooze" feature such that they "*could delay the desk moving if [they were] working on something important or on a video call*" (P2), while three participants wished for a "*more obvious notification before the desk moves up or down*" (P7).

The remaining participants (7/16) preferred the manual desk over the autonomous one. Four desired having control over the desk and two found the autonomous motion a source of disruption. For example, P5 mentioned that "*I spend much of my day meeting with people at my desk. Thus, I would prefer to have a desk that didn't move independently...*" while P13 found the automatic movement "*jarring and distracting. It would be more productive for me to choose when to change the height*". In terms of suggestions for improvement, a few (4) mentioned that they wished the manual desk had a reminder feature. One desired having "*a tone to remind me to move a little*" (P1), while another wished there was "*a timer that you can use to set your own automatic schedule*" (P8).

5 DISCUSSION & FUTURE WORK

While the in-the-moment ratings for the desks were similar, participants voiced bipolar mixed impressions over their preference of desks suggesting that the user's experiential impression and reflective impression may not always align. While half of the participants preferred the manual desk over the autonomous desk due to its distraction and lack of control, in-the-moment ratings show that participants were similarly receptive to both desks, providing preliminary evidence that a simple non-volitional intervention that promotes health, while guaranteeing safety, has the potential to increase adherence to anti-sedentary lifestyle.

The participants' post-study feedback hints that the balance of sense of control and automation is crucial. Half of the participants favored having automation to improve well-being while the other half prioritized having complete control over the desk. This suggests that a compromised option with some automated features that provides a degree of perceived control may be the most optimal. We plan to investigate how users perceive different degrees of shared autonomy and how to best "push" users to encourage usage of sit-stand desks.

As the purpose of this preliminary study was to gather visceral reaction of people, its setup was different from that of a real-world environment in terms of the frequency of desk height changes and task duration. Thus, to study the long-term adoption and adherence to usage of non-volitional interventions, we plan to run a longitudinal study where participants physically work on the sit-stand desks for weeks instead of minutes. Instead of 5 minute intervals between sitting and standing, we plan to use interval of 30 minutes as suggested by recent research [4, 5]. We are interested to see if a users preferred level of autonomy leads to longer and more consistent usage of the sit-stand desks whether that is the autonomous condition where the desk automatically changes height or manual configuration.

This work aimed to explore the possibility of non-volitional behavior change using actuated furniture. While we began with a 1 degree of freedom (DOF) sit-stand desk that can only change its height for simplicity, this concept of non-volitional intervention could be applied to a wide range of actuated objects. There are already instances of such robotic furniture in the form of ottomans [11], computer monitors [10], and drawers [13]. In the future, we plan to investigate using these actuated objects to promote or even enforce different healthy movements and behaviors among users across several longitudinal studies.

6 CONCLUSION

The "haunted" desk is one instance of a non-volitional behavior change that compels users towards healthy movement without them actively having to think about it. Questions about our willingness to relinquish control to these kinds of non-volitional devices to increase our health and well-being is an opportunity that can not be overlooked as our lives are increasingly supported by automation. We present preliminary evidence that a simple intervention that promotes health, while guaranteeing safety, could be enough to increase adherence to anti-sedentary lifestyle and suggests the possibility of further implementing our behavior change approach when less extreme forms of behavior change are not enough to meaningfully influence users.

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