The Haunted Desk: An Exploratory Study of Non-Volitional Behaviour Change with Everyday Robotics

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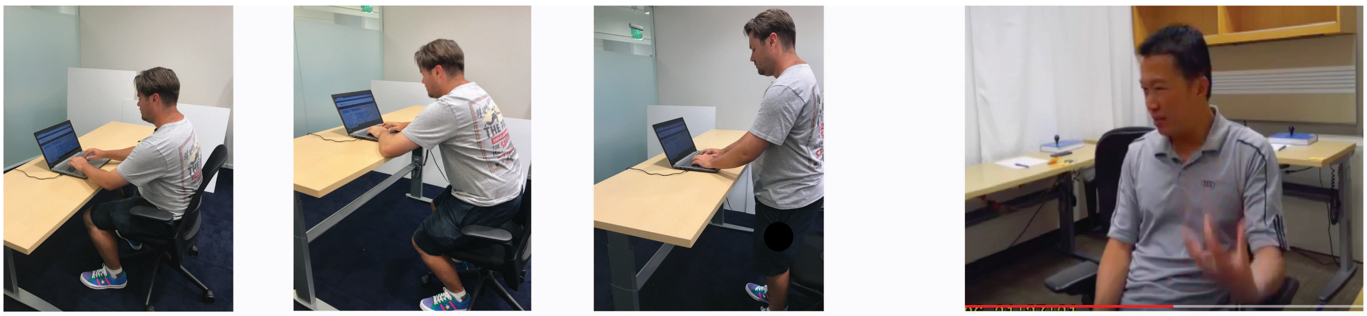

Figure 0 (a-c) A user standing up non-volitionally as he follows the autonomously raising desk (b) from their ergonomic sitting desk height in (a) to their ergonomic standing desk height in (c). d) User response to being coerced into making the positional transition while working at the desk.

ABSTRACT
UPDATED—October 10, 2019. Routine use of sit-stand desks can increase health outcomes, but compliance decreases quickly, and behavioral nudges tend to be dismissed. We introduce robotic furniture that moves on its own to promote healthy movement. We aim to research human interaction with a new category of non-volitional behavior change interventions. In an N=16 study we explored users' impressions of an autonomous sit-stand prototype desk that changes its position at regular pre-set time intervals. Using a within-subject randomized trial on an autonomous desk and a manual sit-stand desk during a video comprehension task, we compared repeated experience measures collected during task, with retrospective experience recall. Results highlight a discrepancy between actual experience and recall of perceived experience. In contrast with prior research that linked movement to task productivity, our low-intelligence health-focused desk seems to be viable for early adoption.

Author Keywords
Robotic furniture; Anti-Sedentary desk; Autonomous; Non-Volitional

CCS Concepts
•**Human-centered computing** → **Human computer interaction (HCI);** *Autonomous Objects;* User studies;

INTRODUCTION
A sedentary lifestyle is increasing with the evolution of the technology age [29, 32] and is associated with poor overall health and mortality risk [12, 19]. Interrupting this sedentary time with frequent light movement has been found to be associated with increased health benefits. [11, 8]. Recent research shows that movement every 30 minutes may help people live longer [9, 8].

Sit-stand desks allow users to alternate between sitting and standing, facilitating reduction of sedentary time and potentially health risk factors [11] (see Figure 0). A large survey of 933 students [2] found that most favored introducing standing desks into classrooms and over half believed it would improve health, attention and restlessness.

However, about one third of sit-stand desk owners use the sit-stand functionality less than once a month [23]. An online survey of 1098 owners found that the reason participants did not use this functionality was that they simply "do not bother" to do so [35], despite awareness of the health implications with sitting too long [4] and a desire for a healthier lifestyle. These results align with prior results showing apathy toward more active use (cf. [35]).

Automation of sit-stand function may act as an agent to replace the users' active decision making for executing actuation. The level of automation and complexity of the decision making agent are both crucial elements with regard to the implementation and long term adaption of an active workstation [21].

We consider the cost to benefit ratio for building a working prototype of an automated sit-stand desk to improve health. Consequently, design considerations start with the minimum features that can increase mobility. Based on iterative design, we implemented a low-cost system that included an anti-pich safety function, a micro height adjustment option, a simple haptic movement notification, an override function, and a time based sit-stand change schedule.

Unlike past work on *comfort-focused* and task-dependent autonomous sit-stand desks [14], we implement a task-independent timer based solution, which represents when a *health-focused* actuation would occur. Our autonomous desk gives the users the option to change desk position or make micro height adjustments at any time during the study. We explicitly compare preliminary user preferences, perceptions of the desk in-the-moment (experience), and retrospectively, and perceptions of participants' own efficacy using the desk across autonomous and manual (user-controlled) modes.

Our main findings are that, people have a strong predisposition to see sit-stand desks as health-devices (i.e. to increase mobility or improve posture. Self-report measures reveal no strong preference between the *manual* and the *autonomous* conditions. Finally, in-the-moment stress evaluations indicated that users were more stressed with the 'manual' desk, but they said that the 'autonomous' desk was more stressful when asked to compare the two at the end of the study. We observed a similar incompatible response for likeability.

These incongruent results led us to believe that it is possible that this minimalistic design could be sufficient to help people habituate with a moving desk that "assists" with their lack of mobility. We propose a longitudinal study, to validate health-outcomes and test temporal effects around using this anti-sedentary desk.

BACKGROUND

Nudges and Autonomous Motion with Robots and Desks

Past work has explored the use of "nudges" (or automatic actions by technology) to influence behavior change. Nudges could increase our likelihood to do the task being nudged, since people will more likely do a task if it is easy [25], as well as our willpower to do other tasks, since willpower is a limited supply that can be depleted if too many decisions need to be made [17]. It is therefore unsurprising that technology is shifting toward autonomous delegation and supervision[16]. For example, [3] had participants interact with a robot that moved its screen to both a high and a low position and found that most participants' posture changed to match the screen's position and that participants were more persistent and more comfortable in the high versus low position.

Previous work has found that merely making the default desk height of a sit-stand desk to be at standing level at the beginning of the day increased standing work rates for employees [33], perhaps because people have a strong tendency to go along with default options [25] and proactive change of desk height requires willpower that may not be available during tasks requiring focus [17].

For robotic furniture, *perceptions of the technology* change when comparing the effect of high-autonomous motion to user-controlled automated motion. In a automated drawer study, [18] participants complete a building task with drawers that either opened autonomously to offer tools or opened at the user's touch. They found that high-automation drawers that moved on their own were disliked compared to predictable drawers.

More recently, Lee et al.[14] proposed a task-based interruption model for autonomously changing sit-stand desk position. In a Wizard-of-Oz simulation, they find that all of their 12 users trusted an autonomous desk more when it actuated during a task compared to between tasks. Furthermore, trustworthiness was prioritized higher than efficiency when choosing their preferred autonomous desk. Overall the autonomous desk was more supportive and less effort than a manual desk. Although they identify timing the *'moment of activation'* as an important consideration for autonomous desks.

However, appropriate selection of *level of automation* [20] is fundamental to mental demands from the operator. Incorrect automation or unreliable implementation may defect the purpose of automation [21]. The value for high-automation is justified when a more viable design is absent.

Cost-Benefit of High-Automation

High-automation robotic furniture requires copious data resources, and complex machine learning algorithms to deliver highly efficient productivity solutions. Implementation of such a complex system may not justify its manufacturing affordability. In contrast, health-focused furniture with low-intelligence would have a higher return value as it is inexpensive, currently relevant, quick to implement, scale-able, and easy for users to understand and accept.

We propose, instead of attempting to train complex automation technology geared to comfort and apparent productivity, to optimize for heterogeneous users' comfort[1] ($11.000) - we explore if humans might willingly permit a low-intelligence system that is cost-efficient ($10 in materials) ($810 - including the cost of the desk) to guide them for better health.

Constant Scheduled Interruption Reduces Interruption

A scheduled interruption is restricted to a prearranged schedule, such as once every 30 min. People would need some control over the initiation of those interruptions. It reduces interruptions as expert users can develop mental models of expected interruption, and over time internalize contextually defined expectations for the type and timing of automation.

Constant scheduled interruptions works as a solution to reduce the cognitive load of interruptions in the same way. *"If a person knows that they will receive a constant, unending, stream of interruptions, then none of these interruptions are a surprise."*[16]. A study in an office environment found that

[1]https://www.stirworks.com/f1detail

easily predictable and reliable anticipation of interruptions resulted in employees not feeling interfered with their work due to differentiated expectations [26].

STUDY 1: ONLINE SURVEY

We sent pre-study online survey questionnaires to N = 40 US adults and recorded responses from N = 39 participants about perceptions towards an anti-sedentary desk. Participants were recruited using Qualtrics survey system. None of the participants were exposed to the concept of the autonomous desk or to the desk itself at the time of this survey. The questionnaire included 38 questions, of which only 10 questions directly addressed sit-stand behaviour and nudging. The remaining questions were about unrelated topics and helped reduce participant bias.

All participants reported that they were sitting at a desk for two or more hours each day. Nearly all participants (93%) agree that there are health benefits to frequent movement at work; specifically citing improvements to mental focus and concentration, muscle tension, *'feeling good,'* and blood circulation (Table 1).

Percieved Health Benefits	*Multiple tally N=(39)*
Muscle Tension	13
Blood Circulation	9
Mental Focus, Clarity	19
Feels Good	10

Table 1. All respondents said that physically moving at work more often was good for them, further qualitative responses show that they explicitly mention health reasons for being active during office hours.

A majority of the participants (28) were positive about being nudged to stand up more at work (Table 2); of these, 12 respondents imagined that the nudge would help with reducing mental absenteeism such as, *"nudging would help me break my routine when I am too engrossed"*; as well as to enable breaking out of the habit of long sitting *"the permission to not be confined to the unhealthy habit of sitting too long "*.

Openness to Nudges	*Multiple tally N=(39)*
Yes, to break habit of long sitting	12
Yes, already moves regularly	10
Yes, generally good for health	6
Nudge not preferred	11

Table 2. Responses to survey about openness to being nudged to move more at work. Most are receptive to the idea of external nudges.

Participants who thought nudging was not the solution for them (11), hypothesized it to be poorly timed, stressful, and disruptive to work. Equal number of the respondents (11) reported that they pro-actively move at work often, and explicitly endorsed the benefits of being physically active at work.

Users have a clear perception of the benefits and see that users are willing and receptive to movement

AUTONOMOUS ANTI-SEDENTARY SYSTEM DESIGN

For this study, we designed a non-volitional sit-stand desk that forces users to sit and stand periodically throughout the day. Keeping in mind the tradeoff between coercion and user authority, our system gives the user control over the desk height presets as well as height adjustments, but also forces them to change position periodically.

Development Iterations

Early desk iterations based on user feedback from preliminary pilots *N=23* led to the inclusion of the anti-pinch safety feature.

Finding the ideal sitting and standing desk height for study participants was challenging. We chose the ergonomic height which was found uncomfortable by users who sometime used micro-adjustments. We saved the users height preferences on the autonomous system for subsequent position changes. For this study, we did not intend to find ergonomic comfort measures. In addition, short term discomfort to ergonomic height suggestions is foreseen [29].

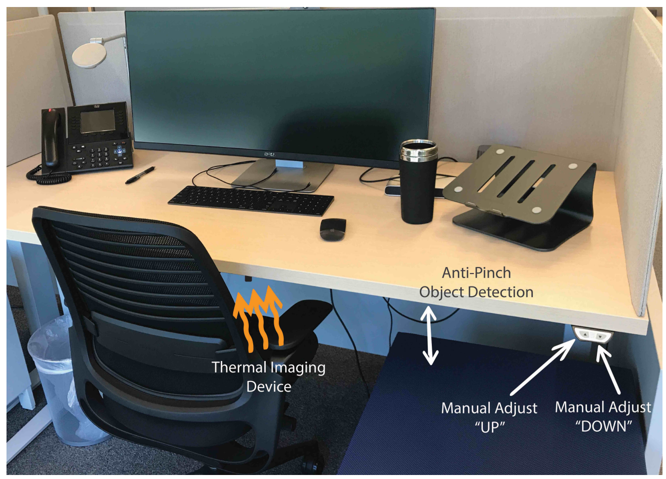

Figure 1. System design: Store bought manual sit-stand desk modified to enable autonomous movement at pre-set intervals, fitted with anti-pinch for safety and thermal camera to detect presence and movement.

Desk Modifications

To do this, we modified a Conset 501-27 Height Adjustable Desk to change position automatically at a pre-adjusted time. Users interact using two buttons: UP and DOWN. While a button is held down, the desk raises or lowers respectively until the button is depressed. Pressing UP twice in short succession raises the desk to the preset standing height, and pressing DOWN does the same for the sitting height. Desk movements are controlled using an Arduino Nano, an Ultrasonic Distance Measuring Module and a DC Motor Driver. A button and height logger is used to verify the system accuracy. Moments prior to desk actuation, a notification to the user in the form on a single gentle buzz from the desk occurs.

STUDY 2: PRELIMINARY EMPIRICAL STUDY

We conducted a preliminary N = 16 within-subject exploratory evaluation of the autonomous standing desk intervention on a subset of the pre-study survey participants.

Category	*Isolated Response Difference*	*Forced Comparison*
Productivity	0	-0.5
Stress	-0.1	0.5
Safety	-0.4	-1
Likability	-0.1	-0.1

Table 3. Difference in perception when evaluating desks as a stand-alone experience vs. deliberate comparison post-study

Methods

Each user entered a simulated office room with two desks. The room was distraction free with no window access to control for environment influence. The desk heights were adjusted by the experimenter based on the participant's height and using an ergonomic desk configuration calculator [28]. Both desks were at the sitting condition at the start. A video camera was placed behind the participant to capture physical responses to the sit-stand desk moving autonomously.

Participants were assigned alternatively at random to start on one of the desks and then moved on the next desk. The intervention desk was fitted with the system described above and was pre-set to automatically change position every 5 minutes. The control desk had an identical interface and manual button controls as the intervention desk, but did not move automatically. At each desk, users completed video comprehension, reading and typing tasks on a laptop for a 15 min duration, followed by a experience survey questionnaire before being moved to the next desk.

We collected data at three points during the study i) post-exposure reactions at first desk (survey) ii) post-exposure reactions at second desk (survey), and iii) both desks intentional comparison after study completion (survey + interview). Measures of productivity, stress, safety, likability, and how strongly they would recommend a desk were studied using Self-reported feedback. The questionnaire was a combination of the a seven point likert scale, which was normalized to a scale from -3 to 3. Gradiants on this scale represent how strongly the participant's experience changed with regard to desk preference. In addition to this data participants also completed qualitative responses to open ended questions.

In this study, we collected post intervention data using a triangulation method with interviews, online survey, and observational data to increase validation. The data was analyzed independently by 3 researchers for inter-rater reliability. Themes were identified using grounded theory [30].

Results

Quantitative Analysis

Prior to starting the study, all of the users established a direct relationship between health and sit-stand desk use (16/16) and most participants (14) brought up health as the primary outcome of the sit-stand desk, focusing on relatively immediate benefits such as posture (7) and blood circulation (6). During the end of the study survey, a majority of users (12) were open to letting the desk force them to change positions in comparison to using a reminder. Users estimated that the manual desk was better for productivity(13) and the autonomous desk to help them be healthy(10).

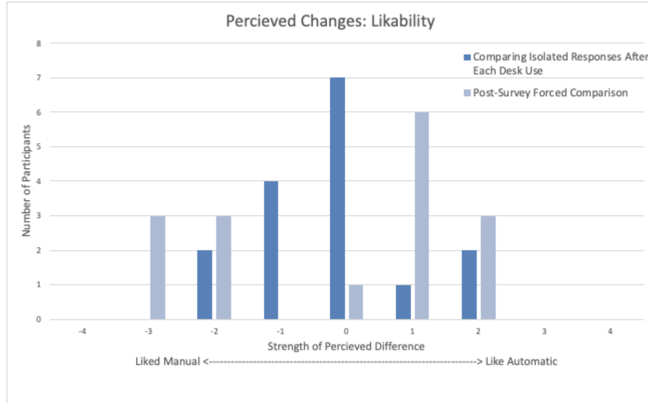

Figure 2. Comparison of in-the-moment experience and reflective forced comparison values for Likeability

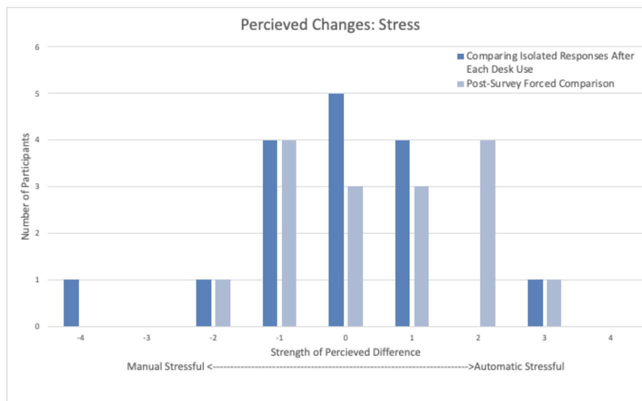

Figure 3. Comparison of in-the-moment experience and reflective forced comparison values for perceived Stress

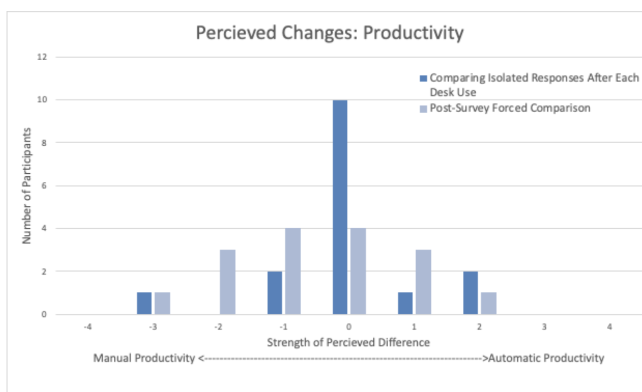

Figure 4. Comparison of in-the-moment experience and reflective forced comparison values for perceived Productivity

In-the-moment evaluations showed no differences between the desk for perceived productivity (Figure 4), nor stress (Figure 3). Users expressed a mild preference for the manual desk with respect to safety (Figure 5); and likeability (figure2. On the other side, post-study forced comparison between the two

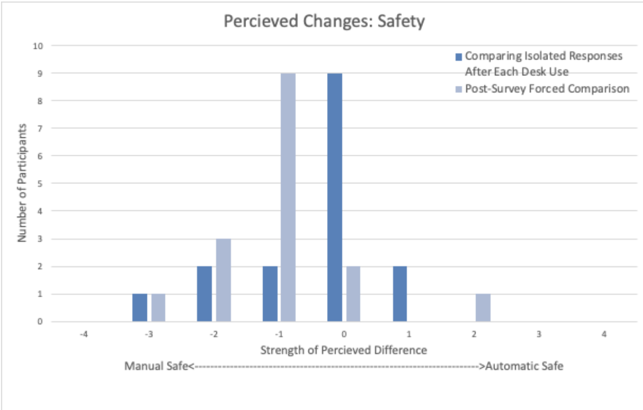

Figure 5. Comparison of in-the-moment experience and reflective forced comparison values for perceived Safety

desks found mild positive inclination towards the manual desk, users indicated that they were marginally more productive on the manual desk (Figure 4), slightly more stressed on the automatic desk (Figure 3), safer on the manual desk (Figure 5), and that they marginally liked the manual desk more (figure2.

Table 3 show the average values for in-the-moment experience, and reflective forced comparison values. The minor differences in stress and likeability lead us to believe that there is a fertile ground for people to adopt, test, and potentially habituate to the use of our simple automatic desk implementation, as long as the safety concerns are proven not to be a problem.

Qualitative Evaluation

Some of the users (5) indicated that they believe their productivity might increase as they continue to use the desk. One user stated that *"Productivity would seem to come from automated variety, at least for me" (p314)* and another said *"I think the changing position makes me more focus and alert" (p08)* indicating that, without distraction, an automatic sit stand desk may help with productivity.

Despite some initial expressions of discomfort, some users offered explanations highlighting that they might get assimilated over time (6/16), such as *"Um, maybe at first it might be like a slow down productivity, But maybe afterwards, once people get used to it and start I guess getting comfortable, both standing and sitting down. I feel like there might be, some productivity increase. For sure" (p312).* This indicates that, after some time, discomfort may decrease as users adapt to using the desk.

Overall, the concept and usefulness of an autonomous desk were perceived positively, *"This is me! I have a reminder app on my laptop for taking breaks and I often ignore it. I really think this (autonomous desk) prevents you from forgetting. You don't have much choice at that point!" (p316).*

DISCUSSION

Experience Measures and Post-Experience Measures

We observe from both studies that participants draw a clear link between frequent movement and benefits to blood circulation, mental focus, and posture. Both pre-study and post-study data indicate willingness to be nudged to reduce sedentary time at work.

Perceived usefulness and perceived ease of use are key predictors of user acceptance of new technology in the work-place as illustrated in the Technology Acceptance Model (TAM)[5]. We find users perception of an autonomous sit-stand desk is present, but unclear for ease of use, however the desk is designed minimally to support ease of use.

Preliminary trends from the empirical study indicate that users do not find an overwhelming difference in productivity whilst using the intervention desk and the control desk. Also, users did not seem to indicate that they overwhelmingly liked one desk over the other from the experience sampling data.

However, for the stress measure, the retrospective analysis indicated a higher perceived stress of the manual desk contrary to the in-the-moment measure for stress. This inconsistency highlights that users have a difference in actual experience and recall of perceived experience. This observation leads us to question whether the basis of the responses to the autonomous desk goes beyond a physical experience.

Future work

Experience with technology is an important moderator of user acceptance of technology [34]. Social norms and ease of use become less important, and perceptions of long-term consequences become increasingly important, as a person gains more experience with a technology.

As a next study interest, we focus on longitudinal questions aimed to give more clarity on i) user interruption to a timer based autonomous desk over time, ii) changes in perception towards desk and reduction in siting time[24], and iii) perceived and measured changes in mental health, physical health and lifestyle changes after prolonged use of the autonomous sit-stand desk at work [1, 27, 7, 13, 6, 15, 31, 22, 10].

To address the need for users micro height adjustments, we have implemented a design where the user adjusts their standing or sitting height using the UP or DOWN buttons, and leaves it at the position for a period of 1.5 minutes, the desk will set this height as their new standing or sitting preset.

CONCLUSION

The "haunted" desk 'forces' users into healthy behavior without them actively thinking about it. The question about our willingness to relinquish this control to non-volitional devices to increase our health and well-being is a bigger question that can not be overlooked as our lives are increasingly supported by robots. We present preliminary evidence that a simple intervention that promotes health, while guaranteeing safety could be enough to increase mobility.

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