The Effects of Interruption Timings on Autonomous Height-Adjustable Desks that Respond to Task Changes

Bokyung Lee
KAIST
Republic of Korea
bokyunglee@kaist.ac.kr

Sindy Wu
University of Florida
USA
sindywu@ufl.edu

Maria Reyes
KAIST
Republic of Korea
mariajoserc94@kaist.ac.kr

Daniel Saakes
KAIST
Republic of Korea
saakes@kaist.ac.kr

ABSTRACT

Actuated furniture, such as electric adjustable sit-stand desks, helps users vary their posture and contributes to comfort and health. However, studies have found that users rarely initiate height changes. Therefore, in this paper, we look into furniture that adjusts itself to the user's needs. A situated interview study indicated task-changing as an opportune moment for automatic height adjustment. We then performed a Wizard of Oz study to find the best timing for changing desk height to minimize interruption and discomfort. The results are in line with prior work on task interruption in graphical user interfaces and show that the table should change height during a task change. However, the results also indicate that until users build trust in the system, they prefer actuation after a task change to experience the impact of the adjustment.

CCS CONCEPTS

• **Human-centered computing** → *Interaction design theory, concepts and paradigms*; • **Computer systems organization** → *External interfaces for robotics.*

KEYWORDS

Robot ; Tasks/Interruptions/Notification ; User Experience Design ; Workplaces

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1 INTRODUCTION

Desk configurations are highly personal [3] and depend on the user's anthropometrics as well as on preferences, habits, [18] and tasks performed [15]. Desk-related work is also a known cause of musculoskeletal discomfort and disorders. Prolonged, static postures need to be avoided [13, 20]. Specifically, sedentary behavior is increasingly being recognized as a potential health threat [35]. Advances in ergonomic knowledge have led to adjustable office furniture, such as chairs and display risers. However, the pitfall of the adjustable workplace is that correct usage requires user participation [5, 7, 16, 24, 36, 38].

Electric height-adjustable, sit-stand workstations [14] are easily adjusted in height and allow switching between sitting and standing. The aim is to introduce movement and vary the distribution of static load through frequent posture changes [15, 22, 40]. Studies [10, 22] have shown that new users choose to stand between 20 and 30 percent of their day. However, long-term studies indicated that only a few users make use of the height changing feature [40].

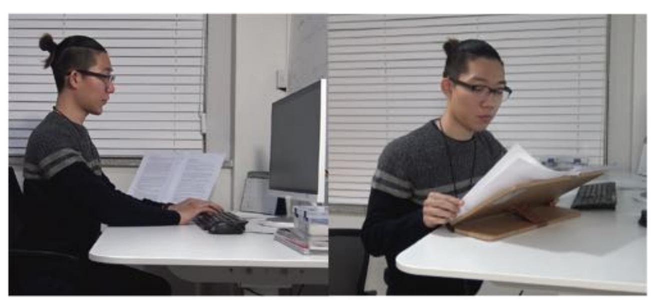


Figure 1: In this study we looked into activation timing strategies for autonomously height changing work tables. The tables adjust to a diverse set of tasks both for standing and sitting working.

In this paper, we address the problem of manual electric height changing tables not being effectively used and possibly not achieving the intended long-term health benefits. The overarching goal is to provide automated and task-specific desk heights that are effortless and non-obtrusive. We expect that strategies in minimizing task interruption in graphical user interfaces [1] are applicable to actuated furniture, because the theory was built from the "cognitive load of general task interruption", and assumed it could be applicable for any type of task interruption scenario.

A situated interview study with long-term users of sitting-standing desks, indicated task changing as an opportune moment for automatic height adjustments. We evaluated two timing strategies for autonomous activation in a second user study with 12 participants (predominantly male students from a variety of departments in KAIST and with no prior experience with height changing desks (except one). The results show that the predicted best moment for automated and task-dependent height changes (during a task change) resulted in less frustration and were preferred for work efficiency. However, changing the height after a task change contributed to building trust in the system in the early stages of use.

We extend the current work on actuated furniture and contribute an initial set of design considerations that are useful for designing unobtrusive interactions. We propose an interaction that starts with trust building through post-task-change actuation and continues with more efficient during-task-change actuation.

2 RELATED WORK

A large body of work in HCI considers health and comfort in the workplace. Body2Desk [19] supports users to configure a fitting desk in Virtual Reality with embedded ergonomic guidelines tailored to the individual. ActiveErgo [41] is an actuated desk that automatically configures itself based on the user's anthropometric measurements captured with a camera. Likewise, Wistron patented a desk [34] that automatically adjusts its height by measuring the distance between the tabletop and the user's knees. Conversely, we aim to support dynamic, active postures rather than static postures.

Several systems provide real-time feedback on the users' poses [8] ranging from obtrusive methods such as body worn vibrotactile actuators [44], shaking monitors [4] to unobtrusive visualizations [39]. These systems aim to assist users in maintaining good posture over time; however, they do not consider the configuration of the workspace in conjunction with the pose. Lean and zoom [9] adapts to the user's pose by adjusting the content zoom to the user's proximity. The actuated Monitor prototype [27] attempts active posture correction by translating and rotating on-screen content.

Smart Workstations and Furniture

Autonomous adaptive desks that support users' working styles are the holy grail of (ergonomic) desk design. Transform [37] shapeshifts to support users' work preferences. Likewise, Living Desktop [2] consists of an actuated monitor, a mouse, and a keyboard. The devices both adapt to the user's behavior, as well as improve work habits (e.g. tidying the desk, improving pose). Closest to our approach is the Salli Autosmart desk [29], which automatically changes height when it detects typing or reading according to pre-programmed personal preferences. We built on these works and investigated user experience and efficiency with timing strategies.

Interacting with Autonomous Furniture

Other projects looked into activation strategies [17] or trade-offs between control and automation. The Stir desk [6] learns from the user and collects height settings and work patterns. Instead of autonomous movement, the desk suggests an occasional height change with a gentle up-and-down motion. Users initiate a height change with a single click on a touchpad to go to the next (most likely) position, but are also free to ignore or snooze the suggestion. Spadafor et al. designed moving robot sofas with personalities [30] and argue that anthropomorphic behaviors help users understand the intent of a robot and help them to anticipate. Similarly, Sirkin et al. designed motions for an autonomous moving footrest. Movements were initiated by "standing up"and finalized by a "sitting down" metaphor, while path and speed were tuned to show the user the robot's intent [28]. The Movementable shape-changing table [31, 32] employs on-screen guidance to communicate locomotion intent.

Task Interruption

In addition to showing intent, the timing of actuation might be important. Interrupting users can cause emotional stress and annoyance and explains the body of work on posture correction [8]. Adamczyk et al. argued that when systems need to interrupt users with pop-up windows, they should do that between *"coarse breakpoints"* (e.g. while switching desktop applications), not between *"fine breakpoints"* (e.g. between entering a username and password) [1]. Similarly, Iqbal and Bailey used mental workload to predict when to interrupt the users [12] and arrive at the same conclusion. We built upon these insights and explored breakpoints and timing in autonomous shape changing furniture.

3 FORMATIVE STUDY

In a situated interview with four participants (mean age = 23, 1 female, 3 male), we aimed to understand when, why, and how people change desk heights in daily life. All of the participants were active users of *electric height-adjustable desks* for more than six months.

Prior to the interviews, we had the participants keep a week-long diary of their desk use. They logged when, how often, and for what reason they changed the height of their desk. During the interviews, we asked them to reflect on their desk use, including the moments that they wanted to change the height of their desk but did not or could not. We voice recorded the interviews and analyzed the data through bottom-up affinity diagramming.

Results

The participants were aware of their posture and adjusted the height of their desk three times a day on average. Height adjustments included both small adjustments and switches between sitting and standing. Typically, they made adjustments when 1) entering or leaving the desk area, 2) taking a pause, 3) during micropauses, or 4) during a task change.

The participants generally changed the height when they ***returned*** to their desk and set the height depending on the time of day or what task they would be doing. Also, pauses (breaks at the desk) were opportune moments for height adjustments, and these happened mostly when working for a long time, feeling tired, or encountering musculoskeletal discomfort.

Participants reported ***changing their pose during a micropause*** such as stretching their shoulders or straightening their back during a typing task. P3 for instance, often started in a good position, but after several minutes started to lean on the backrest and changed the height of the table for comfort. Although they reported micropauses as a good time to make minor height adjustments, most participants did not actuate their desk.

Changing Tasks was mentioned as an opportunity to set the desk accordingly. Yet all of the participants indicated that it took too much effort and felt that they lacked the knowledge to select a height that best fit the task. P2 mentioned that he often multitasks, so the height cannot be set in a task-specific way. Nevertheless, he thought that small automatic adjustments could be useful to refocus (like a forced micropause) when he is reading and gets sleepy. Some participants compromised and changed their pose instead of changing the height. For example, when P2 started to watch a video while the monitor height being set for typing, he prefered leaning back instead of raising the desk height.

Desk Height is Personal. Two participants set their height based on what they would consider good posture, around the chest area with their arms slightly above 90 degrees. However, P4 cared more about the monitor being at eye level than a good working posture, and varied among three positions: standing, sitting, and kneeling. On the other hand, for P2, the desk height was based on comfortable posture. When standing up, his desk height was in the lower chest area because he tended to lean forward. When he was sitting, the desk height was right above his legs as he tended to lean backward.

Noise and Speed are the main barriers when it comes to changing desk height. Two participants reported being distracted by the noise when other co-workers changed their desks and as a result avoided height changes so as not to disturb others. However, the noise also reminded them to change the height of their own desk. The duration of the height change was also reported as a barrier. P1 for instance, would only try to find the optimal position for 20 seconds before stopping for 5 minutes and then doing it again for 20 seconds as he deemed the noise for more than 20 seconds too distracting for others.

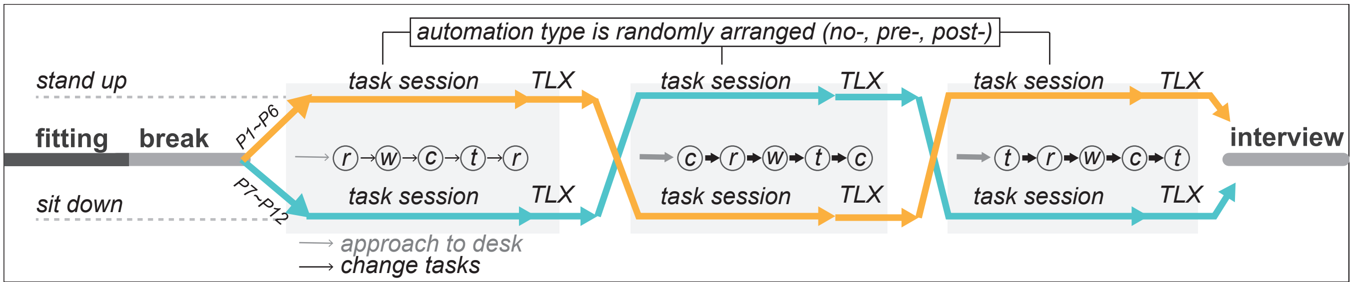
4 SYSTEM DESIGN

We distinguish two types of height changes: 1) task dependent, and 2) between sitting and standing. Ergonomic literature recommends that people with electric desks work standing up to 50 percent of the time. Returning to the desk after a break was found to be an opportune moment for switching between sitting and standing. Pauses at the desk between tasks were indicated as good moments for task-dependent height changes. Participants indicated task-specific height adjustments as desirable, but pointed to the effort searching for the appropriate height as a barrier. Micropauses would thus be an opportune time for a smart preset height setting such as “comfort”, “active”, or “healthy”.

Supervisory Control System

Ergonomic literature recommends frequent pose changes and suggests that comfortable poses might not be recommended poses. Therefore, we designed autonomous desk interaction as a supervisory control system [26] with foreground and background interactions [11]. The desk monitors the user’s activity and anticipates user need by controlling the height automatically. When the user is taking a pause, the desk might decide to switch between standing and sitting modes. When the user changes tasks, such as from reading to typing or crafting, or takes a micropause, the desk optimizes its height. The user acts as a supervisor for this system and through manual controls corrects the height based on preferences, and the system learns from each new preference that is selected.

Autonomous automation can be unanticipated, undesired, or disruptive. Therefore, we see the key design challenge as letting the desk adapt by utilizing a variety of poses that are required for optimal task comfort and health while minimizing disruption.



1st Task Session	2nd Task Session	3rd Task Session
r *read the manual for paper cutting art*	c *cut a paper art template with a knife*	t *type how do you feel about dumplings*
w *watch tutorial video for paper art*	r *read interior magazines and select good house*	r *read a short story about duplings*
c *as a practice, cut the paper with a paper knife.*	w *watch a video of '2018 interior trend'*	w *watch a short clip "Bao-Disney"*
t *type the concept you want to create*	t *describe the interior that matches well*	c *craft dumpling-inspired paper cut art*
r *read the concept book, and select one template*	c *finalize the paper cutting process*	t *type how your craft was motivated by materials*

Figure 2: We started the study with a fitting session in which a participant set task-dependent prefered heights both for sitting and standing. In three sessions we had participants perform a set of tasks. The participants alternated between standing and sitting per session (half started with standing. Every participants experienced all the timing conditions (none-, pre-, post-), but in a randomized order. A TLX survey was conducted after each session and the study was concluded with a post-interview.

5 THE STUDY

Based on task interruption literature, we assume that the best moment to change desk height is between tasks **(pre-task-automation)** and the presumably worst moment is during a task **(post-task-automation)**. We define "best" as the "least obtrusive (minimum frustration and annoyance, while providing best support)". We compare these two activation timings with a not automated, but manually operated height changing desk.

We recruited 12 participants (mean age=23, 2 female, 10 male) from a local university who use their desks more than six hours a day. All of them, except one, had no prior experience with manual or electric height-changing desks. We prepared four tasks that, according to ergonomic guidebooks, require different optimal heights: *typing, watching, reading, and paper cutting*. In a within-subjects study design, we guided participants through three sessions of four tasks and recorded both quantitative and qualitative feedback.

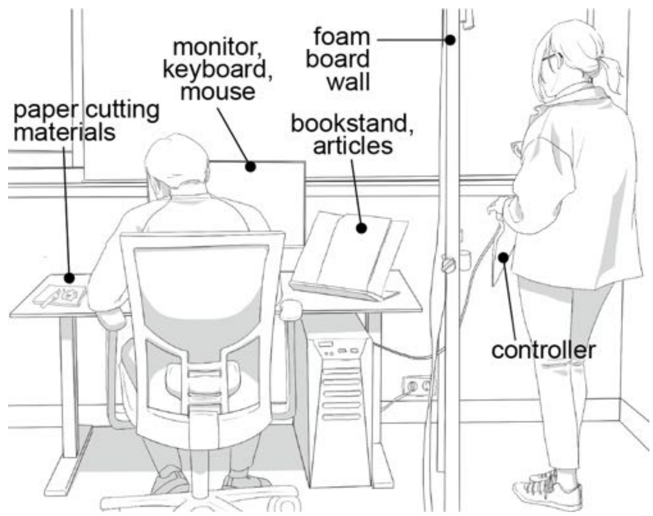


Figure 3: The study setup consists of a hacked electric height-adjustable desk. The participants could manually control the desk, but the desk was also controlled by one of the researchers as a Wizard of Oz, hidden from the user.

Setup

We hacked an IKEA Bekant Sit-Stand Desk, so that we could control it both with the up-down buttons and with remote control software. We replaced the electronics with two Cytron 10Amp DC motor drivers and W138 Hall effect sensors as encoders all controlled by a Teensy Arduino. We adjusted the speed to match the original speed of 30 mm per second. The control interface was made with Processing [25] and communicated through a USB/serial with the Teensy. The interface had buttons for each task to program a preset or to move or delay-move the table. We located the desk in a laboratory decorated as an office as shown in Figure 1.

We employed the Wizard-of-Oz approach [21] similar to related studies [23, 30, 42]. The Wizard observed participants from behind a wall and actuated the desk with the control panel. We standardized the moment of activation for pre-task adjustments, such as when the participant reached for a book or opened the word processor. For post-task adjustments,

Task	Type	Interaction Trigger
typing	pre-	when a person turn on the Microsoft Word.
	post-	when a person starts typing with keyboard.
cutting	pre-	when a person prepare a paper template and grab a knife.
	post-	when a person starts cutting a paper.
watch -ing	pre-	when a person prepares to watch a video.
	post-	when a person starts watching a video.
reading	pre-	when a person grab a book from a shlef.
	post-	when a person starts reading a book.
approch-ing	pre-	when a person start moving towards a desk
	post-	when a person is approached to a desk.

Table 1: This table shows the participant's behaviors that trigger the activation of a desk. The operator actuates a desk based on these rules.

	watching	typing	cutting	reading
watching		M=9.61 SD=3.91	M=7.30 SD=4.54	M=8.30 SD=3.70
typing	M=6.66 SD=4.64		M=3.30 SD=3.56	M=2.69 SD=2.49
cutting	M=5.44 SD=4.98	M=3.04 SD=2.31		M=3.67 SD=4.73
reading	M=5.97 SD=4.47	M=2.13 SD=1.87	M=2.35 SD=2.67	

Table 2: The fitting procedure resulted in unique personal and task-dependent heights both for standing and sitting. The table shows the average relative height differences between tasks in centimeters.

we delayed activation by 10 seconds, to make sure that the participant started the task.

Procedure

Prior to the study, we briefly introduced the goal and process of the study to the participants. Then, we conducted a ***fitting session***. We asked the participants to find comfortable heights for each task both for standing and sitting (a total of eight heights) and recorded the settings in the control panel (Figure 2).

In three session we asked participants to go through several tasks, as shown in Figure 2. Each task was three minutes long and delivered through a small display on the tabletop with a sound notification. We tested activation timings per session and the order was randomized between participants. We alternated sessions between standing and sitting, with half of the participants beginning in a standing position and the others sitting. After each session we asked the participants to fill out a questionnaire on an adjacent desk. Upon returning to perform the next session, we activated the height change according to the condition. In case of non-automation, we asked participants to manually change the height of the desk before starting the task sequence. In the case of pre-task-automation, we started moving the desk to a neutral position upon approach. As soon as the "moment of activation" was observed, the desk moved to the correct height.

After the three sessions, we conducted a semi-structured interview to ask about their general feelings or thoughts towards each strategy.

TLX Measurement

We used a modified NASA-TLX survey to measure workload (Table 3). The Physical Demand scale was replaced by Annoyance, following Adamczyk et al [1]. The Time Pressure scale was removed as we did not ask participants to finish a particular task; instead, we let them work for a given amount of time. We included two additional scales: Engagement ("How well you were engaged in a task set") and Support ("How you felt the desk supported your task sequences"). The survey was administered on paper rather than on the computer to provide a clear distinction between tasks and to use as interview material.

6 RESULTS

All of the participants were aware of the necessity of good posture. Only P7 used an electric height-adjustable desk at home, and was already familiar with height-changing interactions. Participants who worked on a fixed desk employed several strategies to make the desk fit their use, such as using DIY monitor stands (P8), using height-adjustable chairs (P7), or adjusting their work pose by leaning back or forward (P5, P6, P9). As shown in Table 2, the fitting session resulted in unique, personal, and task-dependent heights both for sitting and standing work.

In the concluding interview, participants reported positive impressions towards desks that automatically updated height based on the task and agreed that the self-actuating interaction led to more enjoyable experiences at the desks. As most of the participants had no experience with a height-adjustable desk, the novelty of the concept might have evoked positive feelings.

A non-parametric, one-way, within-subjects analysis of variance (Friedman-test) was conducted to evaluate if there were differences in each TLX measurement between conditions. As shown in the Table 3, there are significant effects on frustration, engagement, mental effort, mental demand, and support ($P<0.005$), but not on annoyance or performance.

TLX Measurement	X^2 (Chi-square)	P
Annoyance	X^2 (2, N=12) = 0.632	0.729
Performance	X^2 (2, N=12) = 0.600	0.741
Frustration	X^2 (2, N=12) = 12.789	0.002*
Engagement	X^2 (2, N=12) = 7.2	0.027*
Mental Effort	X^2 (2, N=12) = 13.886	0.001*
Mental Demand	X^2 (2, N=12) = 6.889	0.032*
Support	X^2 (2, N=12) = 17.333	0.000*

Table 3: The main effects for TLX measurements from the Friedman Analysis (non-parametric one-way ANOVA) are shown. There are significant effects (α = 0.05) for Frustration, Engagement, Mental Effort, Mental Demand, and Support.

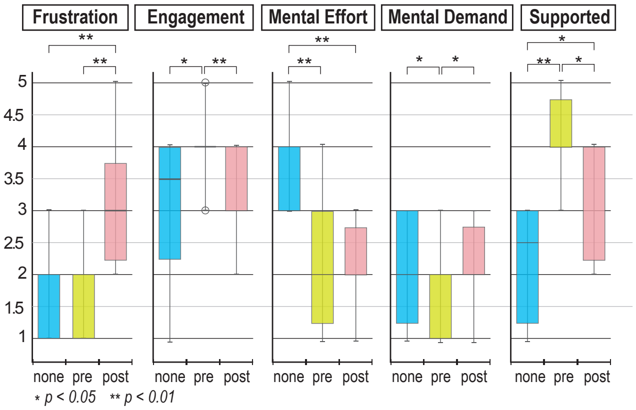


Figure 4: A (A Wilcoxon signed-rank test details the differences between conditions.

To examine where the differences actually occurred, a post hoc test (Wilcoxon signed-rank tests) was performed, as depicted in Figure 4. Interaction type had a significant main effect on the feelings of being supported; but for other TLX measurements, we found a significant impact only in particular pairs (see Figure 4). The details are described below.

Non-automation

Although participants in the fitting session prefered a desk height that was unique for a given task, in non-automated conditions they only changed the height occasionally. Most of the participants changed the height only when the difference between the current height and the preferred height was over 60mm, for example when they changed from standing to sitting or switched the task from *"watching"* to *"other tasks,"* or vice versa (Figure 2).

On the other hand, the participants typically ignored minor height differences (less than 35mm difference on average) in the first session, but when they got tired in the third session, they started making adjustments. P6 mentioned, *"Although I found a good height at the start of the study, when I was using the desk for a while, I made minor adjustments to improve my comfort."* The participants went through several iterations in a trial-and-error process (about 2-3 times) before they found a comfortable position.

The iterative manual adjustments distracted the participants from their work, as they needed to find a comfortable desk height while working on their tasks. P6 commented, *"I was bothered because I had to think about two things (setting the height & the task) at the same time."* All of the participants stopped working while they were adjusting the height, which delayed their work. They spent approximate 20 seconds out of three minutes on their minor adjustments. Eight participants out of twelve complained about the speed of the desktop movement. This might explain the results in the Table 4; there was a significant burden in mental effort between non-automation and other interactions.

Additionally, the participants pointed out that they found it difficult adjusting and experiencing the height at the same time. For tasks that require their hands (e.g. hands on keyboard), they had to alternate posing and controlling the height with the buttons on the controller.

Although 10 out of 12 participants generally reported negative opinions toward manual interaction, the other two mentioned that they felt more comfortable having full control.

Pre-task Automation

During the pre-task-automation session, the tabletop was actuated during the task change and before the participants started working. This resulted in a smooth process and the participants focused on the task for the entire three minutes. None of the participants wasted time watching the tabletop move or selecting an appropriate height.

The duration of height changes was faster than the time participants needed to change their task. It took more time when changing tasks between watching and typing, but the participants barely noticed.

The TLX survey indicated that pre-automation scores were the best for *time efficiency*, but also *concentration* and *work engagement*. The TLX survey results also indicated that pre-automation significantly improved work engagement compared to post-task automation or non-automation. Also, the mental demand was significantly lower in pre-task automation than the other interaction types.

Pre-task automation was favored, especially when the desk started moving when the participant was approaching it. In this situation, they could see the visual movement of

Figure 5: In the post-task automation condition we observed participants perform hand gestures. Some *hovered* their hands during the motion, while others put their hands on the desktop to feel the motion of a desk. Also, some positioned their hand at the expected height, and waited until the desk reached their hands.

a desk from a distance. P6, P9, P10, and P11 mentioned that they felt like the desk was greeting them.

However, most of the participants commented that while they enjoyed pre-task automation they did not fully trust the movement. As the participants did not notice the presence of the operator during the study, few were curious about the activation algorithm. Especially P11 was a bit skeptical: *"The desk was moved in advance, which was very convenient. But why was it actuating? How does the desk know what I am doing? Is it a correct movement? I was not sure about that."* Additionally, P12 indicated that since the desk moved before his action, he felt the desk was forcing him to work on something. P2 also expressed the need for additional notification before movement occurred.

Post-task Automation

During the post-task automation session, the desk started actuating 10 seconds after a participant started a new task. Most of them showed a startled response upon the first moment and stopped working. We observed the participants making various hand gestures during the height change. When cutting or typing, the participants hovered the knife or lifted their hands up during the motion, and resumed when the motion stopped (Figure 5a). Some participants (P1, P8) would scoot their chair back or tilt their head to observe the desk motion. The participants seemed more comfortable with the desk when their hands were on top of the desk while waiting (Figure 5b), and some of them (P3, P6) put their hands flat on the desk as the desk moved to feel the motion of the desk. Three participants (P2, P4, P5) positioned their hands at their expected height and waited until the tabletop hit their hands (Figure 5c).

From the second trial, participants seemed more comfortable with the automation. Some participants (P5, P9) continued working while the height was changing. But the interview revealed that it did not mean that they became used to the interaction. P8 commented, *"I was uncomfortable because the desk was actuated when I didn't intend for it to."* P2 stated that he was nervous for the rest of the time, and worried that it would suddenly actuate during his work. P10 explained, *"I could not concentrate until the desk finished actuating. The reason was that the desk was not moving at the moment that I was expected."* The TLX survey results also indicated that the frustration levels were significantly higher in post-automation than no-automation and pre-automation.

Additionally, some participants pointed out safety issues. They felt scared when the desk was actuating while they were cutting paper. Therefore, they requested sound or haptic notifications before the height adjustment was initiated.

However, all of the participants agreed that the post-task automated desk was more trustworthy. P9 highlighted this, saying, *"I started doing a task at an incorrect height, then after several seconds the desk was actuated to my preferred height. By experiencing and comparing two heights, I gained trust that the height the desk set for me was better"* P8 added that it was more evident that his action was a trigger for the desk movement and it was easy to catch the mental model of the desk.

Additionally, post-automation prevented participants from leaning on the desk, especially when standing. We observed that all of the participants put weight on their desk while standing at first, but this made them uncomfortable when the desk was actuated in this position. Therefore, most of them stood up straight after the first trial and tried to minimize the touch points between their bodies and the desk.

7 DISCUSSION AND FUTURE WORK

We took a step towards understanding user interactions with shape changing furniture with agency. We built both upon the work of Wendy Ju with autonomous objects that interact with users [28, 30], and the prior art on task interruption [1]. We identified opportune moments for adjusting the height of a desk in-use while aiming to avoid interrupting the user. We compared two timing strategies. The ideal timing was found to be **during** a task-change, however, we also found that actuation **after** a task change let users experience the impact of the adjustment which was favored to build trust in the system.

However, our study has several limitations apart from the participants gender, age and backgroud. We employed a Wizard-of-Oz simulation and participants followed a known task sequence. In reality, it is hard to predict what people will do next, ignore false positives such as temporary poses (e.g., a phone interaction), and deal with concurrent tasks (e.g., typing while reading). Nonetheless, a system could learn from users and anticipate their needs based on observed pose changes or on-screen activity, similar to how we instructed the wizard with the “moment of activation”.

In addition, the study only samples a moment in time, and even within this relatively short study, we observed participants change their behavior due to fatigue. Therefore, an in-the-wild study with automatic activity detection should follow to evaluate the long-term effectiveness of the results. As mentioned in the formative study, an in-the-wild study could also investigate the social aspects in offices and actuation strategies involving multi-actuated desks. Future work could also include other aspects of the office environment such as temperature and lighting [43].

Several related works [28, 30, 33] stress the importance of autonomous moving or shape-shifting objects that convey their intent and show that they are aware of the user’s presence. Even though the sound of the desk actuation was reported as disturbing, both the formative and Wizard-of-Oz studies revealed that users require a pre-activation notification which was not studied in this paper. Providing unobtrusive feedforward on actuation and communicating “intent” requires further investigation.

Nonetheless, based on the results we discuss three insights that need to be considered for designing autonomous interactive desks (or furniture): Preferred vs Recommended, Manual vs Autonomous, Trust vs Interruption.

Between Preferred and Recommended

A desk is not designed for computer tasks, and the keyboard is not designed to be used in conjunction with the mouse [14]. Currently the landscape of electronic devices used for work is increasingly diversifying and this requires adaptive and personalized pose recommendations. In addition, this study found evidence that ergonomic recommendations do not always result in a comfortable pose [4] and that comfort was prioritized when participants indicated fatigue.

Framing the interaction as a supervisory control system based on the user’s presets let users experience the desk action in a pleasant manner and this will build trust for self-actuating products. Our study revealed that the participants felt that they had the authority to control and appreciated that the desk did not play the role of an *advisor* that forced them to sit in an unintended way.

Between Manual and Autonomous

Observing participants in the non-automated condition revealed opportunities for manually controlled height adjustments that go beyond the up-down buttons found in today’s desks. Users faced difficulties finding optimal settings because they wanted to concurrently adjust and test, e.g. adjusting the height while assuming a working pose. This procedure required several iterations and was reported as a barrier. Possible solutions could be a foot pedal, voice activation, or a tactile force feedback sensor that detects when the desk provides support for a pose. In addition, constant speed was reported to be an issue, too fast for small adjustments (only in bursts) and too slow for switching between standing and sitting. A continuously adjustable speed with an analog joystick or force-sensitive surface could be explored.

Manual controls can provide synergy when used in conjunction with automation. Semi-automated interactions can let a user initiate desk actuation without requiring manual adjustments. Whereas the Stir desk let’s users snooze an upcoming height change, likewise, a simple button press might initiate a height change.

Between Trust and Interruption

The study revealed that the preference for *automation conditions* is dependent on how much trust was built between a user and a robotic product. Although the pre-task automation condition provided less task interruption, frustration, and mental demand compared to changing the height when the task had started (post-automation), several participants stated that they preferred the latter. Participants seemed to prioritize the level of trust rather than efficiency (or the amount of interruption).

Therefore, automated interaction could be framed as the guidance from novel to routine users, and needs to be adjusted as the user gains trust. Before trust is gained, the desk needs to inform users about the impact of its movement, and persuade them that its actuation will enhance their work experience. After gaining trust, users can concentrate on their tasks regardless of the desk’s movement. In order to figure out when this trust point is reached, a long-term study is required.

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