Co-designing Tangible Break Reminders with People with Repetitive Strain Injury

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Abstract. People with Repetitive Strain Injury (RSI) performing computer work for 4+ hours/day should take microbreaks every hour to reduce their symptoms. Unlike apps and notifications, tangible user interfaces offer the opportunity to provide non-focus-demanding and calm break-reminders in users' periphery. This paper explores this design space to identify the design parameters of break-reminders as everyday things. First, we discuss and analyze our initial co-designing study, where 11 participants with RSI created 9 low-fidelity prototypes. Then, we present our results-led high-fidelity prototypes and demonstrate the use of the findings in directing the design decisions of the technical implementation. Finally, we take our designs back to users in a second study to gain deeper insight on their reflection on physical break reminders. Results show how users designed for calmness and ubiquity in their everyday environment, playful user engagement and emotional shape-shifting among other design qualities.

Keywords: Shape-changing interfaces · Workplace · Repetitive strain injury · Well-being · Everyday spaces · Interactive objects

1 Introduction

Computer-dependent lifestyle and work are exacerbating Repetitive Strain Injury (RSI) [1, 2], which has become a prevalent health issue. Lack of attention to ergonomics of various workplace devices [34] combined with psychosocial factors [3–8] are the leading causal factors and aggravators of RSI. Against this, taking microbreaks (30 s to 1 min) is recommended to reduce the load on activated muscles and provide a mental break to increase productivity [9]. But people find it hard to follow a regimented break routine. Notifications (time-based desktop or phone reminders) can help users take breaks, but

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they are often ill-timed and not aware of the user's natural work pause pattern [10], exacerbating stress and productivity [4]. People with RSI have unique needs regarding notifications, even when a response to promote care and wellbeing would suggest minimizing them. We investigate the need for break reminders that do not disrupt the user's workflow and provide passive awareness while being conducive to productivity. Specifically, we propose actuating everyday objects as a potential solution [11–13] (Fig. 1).

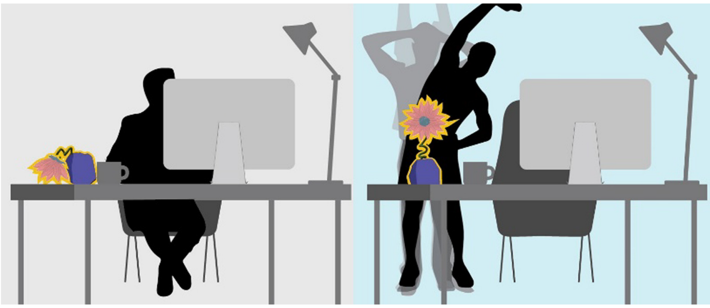

Fig. 1. Interactive everyday objects in the workplace can serve as break-reminders for people with repetitive strain injury. In this illustration, the wilted flower reminds the user to take a break. Once they have, the flower is blooming again.

The study of actuating tangible interfaces as a break reminder so far has only been in preliminary works, which rather focused on the technical implementation with a limited evaluation with end-users (N < 4, without RSI). Our work covers this gap in two rigorous reflective user studies and goes further by engaging people living with RSI symptoms in 4 co-designing activities to ideate and create tangible break reminders for RSI as everyday things that are appropriated for their needs. The first study focused on three research questions: what strategies do people with RSI use to incorporate breaks and other healthy habits? What are user preferences for workplace interactive objects? What do they desire from a tangible object that can support people to take breaks? The second study asked: what impressions, criticisms and reflections did people with RSI have about our implementation of their prototype design?

In doing this research, we further our understanding of the work context in which RSI occurs, contrasting workplace and work-from-home behaviours, the coping strategies, and challenges faced by people with these symptoms. Our goal is not to compare the use of digital or tangible notifiers, but instead to investigate the design space of actuating everyday things as break-reminders by engaging and co-designing with RSI users. We want to inspire designers engaging with actuating physical interfaces and elevate the discussion around tensions between what researchers create as prototypes and what users ideate for themselves. In this sense, our three key contributions are:

- Engaging people living with RSI in discussions by critiquing (2 design probes), ideating (9 low-fidelity prototypes) and reflecting on break-reminding everyday things in a co-design study with 11 participants.

- Proposing 13 findings about break reminders designed by people with RSI in terms of disruption of work, personal preferences, emotional engagement and the social constraints of a workplace versus working from home.
- Designing and implementing 3 high-fidelity actuating prototypes as calm non-focus-demanding break-reminders, using design decisions inferred from the co-designing user study, and gaining user feedback afterwards.

To the best of our knowledge, people with RSI have not been included in user studies related to notifications or break reminders. It is also the first study in investigating tangible devices from a co-designing approach capturing the context and latent needs of the users to formulate a design guideline.

2 Related Work

To explore this design space, we review previous work on RSI, interruptions at work, and actuating everyday things.

2.1 Repetitive Strain Injury

RSI is "pain felt in muscles, nerves and tendons caused by repetitive movement and overuse" [15]. Lack of attention to ergonomics of workplace devices and furniture is a major cause that exacerbates RSI symptoms [1]. While earlier work focused on investigating the impact of repetitive movement, awkward posture, and lack of attention to ergonomics due to prolonged sitting and computer usage [16, 17], recent work demonstrates psychosocial factors like anxiety [3, 4], mental exhaustion [5], social support [6], work organization [7], and time pressure [8] also exacerbate RSI at work. Aside from workplace ergonomics, "healthy behaviour" at work reduces and prevents the symptoms of RSI [18]. These include engaging in regular stretch and rest breaks and incorporating regular physical exercise. The effectiveness of these microbreaks to reduce muscular load is well established [9, 19–21]. Besides releasing muscle strain, microbreaks also reduce the mental strain, which activates the same muscle group as computer usage [5]. This demonstrates the usefulness of incorporating "healthy behaviour" and improving the workplace ergonomics in preventing and reducing RSI.

2.2 Interruptions at Work

Break reminders intervene work to remind the user to move, making it important to understand the cost of interruption on work and well-being. Interruptions in the form of phone and desktop notification do not regard the user's primary tasks, increase task time, and perceived task load [4, 22, 23]. In addition to impacting work and productivity, interruptions in the middle of a user's primary task also increase annoyance by 31% to 106% and double the anxiety [4]. Hence untimely interruptions like generic break reminder software can deter the user's productivity and mental health.

Some HCI research presented non-traditional break reminders to address sedentary behaviour at work [12, 24], using strategies such as interactive breaks [24], non-intrusive reminders [12], or persuasive messages [25]. However, these works do not include the voices of people with RSI who can bring new insights to the study of break reminders. People with RSI may have more experience in trying to incorporate breaks during work as a part of adopting healthy work habits compared to people who do not have RSI. Not much is known about their experience at work and their desires from a device that supports health behaviour such as taking rest and stretch breaks.

2.3 Actuating Everyday Things

Design-led research considerations have shown the value of connecting habitual behaviours in daily lives with acts of checking data through interactive everyday objects [26]. Actuating objects and shape-shifting interfaces are capable of changing their appearance and/or form factors through user interaction or their autonomous behaviour. Several terms have been proposed to encompass this notion such as Shape-changing interfaces [27–29], radical atoms [30] or Organic User Interfaces [31]. Rasmussen et al. [32] and Roudaut et al. [27] have proposed to classify these interfaces depending on their transformations that can include changes in orientation, form, volume, texture, viscosity, or spatiality. Shape-changing interfaces have been used to communicate ambient information through slow movement in the periphery of the user [13, 33]. These changes, when slow and quiet, can exist in the peripheral vision of the user [13]. These functional applications demonstrated in prior work include communicating emotion [34], communicating information [13, 32, 35], dynamic affordances that fit the context [36], and volume change for portability [37].

Further research unfolding the design of everyday computational things [38] suggested experiential qualities that expand the functional purposes of their tangible prototypes. Such examples include furniture [39–43], soft furnishing elements [44–46], decorative objects [26, 47] or fabric [61]. In particular, Shin et al. [43] assessed and proposed to mount a monitor on a robot to slowly correct a desk worker's posture. However, the scope of this research focuses on office desks objects applications and near periphery actuations in the context of break reminding for RSI, not correction.

Limited research has incorporated actuation into everyday objects of the workplace. Seoktae et al. [37] presented an inflatable mouse that facilitates portability through volume change. A few other approaches include: 1) the use of physical and vibrotactile feedback from the chair to facilitate posture change while sitting [48]; 2) shape-change as an ambient notification system during work activities [33, 49]; 3) in-pocket notifications [50]; and 4) deformation for information visualization for diverse datasets (e.g., numeric and textual data, and GIS information) [51]. In BreakAway [12], Jafarniami et al. proposed a shape-changing sculpture resembling a chair placed onto a desktop that suggests breaks through multiple degrees of slouching. They found that the participant appreciated the ability to ignore BreakAway at important moments unlike generic reminders on her calendar. The sculpture succeeded in providing passive awareness as the participant never expected it to completely slouch and took a break as soon as the slouching started. Similarly, Jones et al. [13] and Kobayashi et al. [35] evaluated the effectiveness of shape-changing notifications to provide passive awareness without disrupting the productivity of the user, the first using a self-bending strip, the other propping up a mobile device. They found that the near periphery of the user is ideal for ambient notification to work. Kucharski et al. [14] used a small humanoid robot located on a desk for break reminders, by changing its posture, stomping, and making increasing noise, and participants (4 office workers) indicated potential.

These works demonstrate the potential of interactive everyday objects to provide passive awareness without disrupting the user's primary task. These devices are physical objects that would exist in the environment of the user, the workplace in the case of RSI break reminders. Hence, a co-designing approach that attempts to understand the context, the needs and desires of people with RSI will bring new insights to the existing body of work of interactive break reminders.

3 Study 1: Co-designing Workplace Interactive Objects

In this first study, we conducted 11 individual co-designing sessions to comprehend the potential of interactive everyday objects as break reminders in the workplace for people with RSI. To understand their unique needs, challenges, preferences, and unspoken desires from a break reminder, we divided each session into three activities: 1) User Interview (Q1), 2) Design Critique (Q2), and 3) Co-Design (Q3). Each individual session lasted for an hour, conducted during the winter of 2019. We obtained ethical approval from our institution's research ethics board. Participants received a $30 CAN compensation for their time. The sessions were structured in these three phases to gradually bring participants from a descriptive to a creative state, where each activity was designed to answer a research question:

- Q1 – User Interview: What strategies do people with RSI use to incorporate breaks and other healthy habits?
- Q2 – Design Critique: What are user preferences for workplace interactive objects?
- Q3 – Ideating: What do they desire from a tangible object that can support people to take breaks?

We had 11 participants who had RSI for an average of 7.8 years (21 to 56 years old; mean = 37.6 yo, median = 33 yo; 7 women, 4 men). Their symptoms were in fingers, wrists, back, shoulders, or knees. Nine participants had consulted health experts for their condition and ten of them were actively trying to take breaks. Eight participants were using ergonomic objects or devices including an ergonomic chair, vertical mouse, sit-stand desk, and a document reader. Nine participants had a desk and a cubicle of their own and two participants were moving between different workspaces.

We transcribed 11 h of audio recording from the sessions. For the ideation activity, we supplemented the codes from the audio transcription by interpreting salient design features that were not verbally expressed by the participants and analyzed their sketches and/or low-fidelity designs. The gathered data were all combined and four researchers conducted iterative Thematic Analysis to identify underlying themes, a well-established and rigorous method to analyze qualitative data [52, 53].

We note that to begin this project as well as throughout research process, we talked to experts such as occupational therapists and ergonomists to better understand the requirement from a medical point of view. However, we choose to involve only end-users in this study to fully embrace the benefit of participatory design and better understand how our end-users wanted the intervention to occur within a particular context. Using only end-users within participatory design is a common practice [54].

3.1 Activity 1: User Interviews

We sought to understand the context of working with RSI, challenges faced by our participants and the strategies employed to cope with it. To facilitate the discussion about the participant's work environment, we interviewed six participants in their workplace. The other five participants brought pictures of their office desks.

We supplement the interviews with an observation of the level of privacy, space availability for personal objects, and the presence of personal or decorative objects of preference on or around their desks. We do this to ask specific questions about their personal preferences and feasibility of having a shape-changing device as a break reminder. From the 11 interviews, only one participant was actively using a reminder system. Four talked about having tried notifications and reminders in the past. Another four participants mentioned using their bodies as a reminder to take a break. Rather than following a regular break routine recommended to most of them, they inadvertently waited until the strain in their body triggered them to take breaks.

3.2 Activity 2: Design Critique

To understand the perception of interactive everyday objects as break reminders, we used design probes to encourage participants with RSI to provoke and inspire participants to rethink their environment, and respond in a way that creates a dialogue between the participants and the researcher [55]. Based on the findings of a prior pilot study, we designed two probes to capture users' impressions on introducing interactive objects to their workplace (Fig. 2). The probes gave an actuating form to otherwise static desk objects. We intentionally made the design probes aesthetically crude and in low-fidelity to put less pressure on participants. This will make them more critical, as they do not assume it took a great effort from the researcher to create [56].

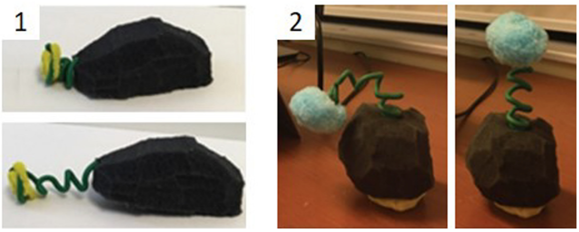

Fig. 2. Design probes: (2.1) springy-mouse (desk object) and (2.2) wilting flower (desk decor).

Probe1. We introduced a mouse probe (Fig. 2.1) with the following fictional story: "The mouse has a small button attached to the spring at the front of the object. The springs extend themselves and the button moves farther away from the mouse indicating a visual cue. You can restore the initial state of the mouse only by taking a break. Tracking the sitting and computer usage happen in the background and the button recoils back to the surface of the mouse once you have taken the break."

Probe2. We introduced a wilting flower (Fig. 2.2) with the following fictional story: "The flower tracks the sitting and computer usage of the user through sensing capabilities that is embedded in the chair and the computer. When it is time for the user to take a break, the flower would wilt, suggesting that users get up and take a break. You can restore the life of the flower by taking a break."

We discussed two versions of each probe: when the flower or mouse was interruptive and whether the wilting and the extension of the spring would affect the user's workflow. When the flower or mouse was disruptive, the withering or spring would decrease the efficiency and potentially prevent the user from continuing work.

3.3 Activity 3: Ideation

While describing their experience and giving their impressions on the design probes, participants often addressed features of the design probes they did not like and made suggestions. We noted these instances to initiate discussion during the design session where we repeated these instances as questions, e.g. "*Earlier you mentioned that you wouldn't relate to a flower, is there an object that you would relate to?*" In answering, participants ideated objects that embodied their preferences and design concepts.

We provided prototyping materials that included a mix of elastic and malleable material to encourage creativity. The elastic materials included elastic bands, foam in the form of sheets, cubes, and rolls. For the malleable materials, we included play dough, pipe cleaners and various types of wires. Additionally, there were small rigid wooden blocks, tape and glue to combine different materials. We also included markers, sticky notes, and drawing sheets to enable sketching during ideation.

Design Concepts. Most participants came up with their own designs of what they personally prefer as a shape-changing object on their desk to remind—and persuade—themselves of their break time. All participants except P1 and P10 used crafting materials to either make a low-fidelity prototype or sketch their design. P1 stated that they were happy with their Outlook reminders and did not find a tangible object desirable due to limited desk space; and P10 preferred *probe2* (the wilting flower) as opposed to another object expressing that the flower would work well for them on their desk. The other design concepts that users developed (Fig. 3) are described below:

- **Snoopy (P2):** A desk toy that stands straight on the desk. When it is time for a break, it collapses and becomes sad. Once the user is back from the break, it stands and greets them with a smile.
- **Blobby (P3):** An animated character pinned on a wall board. It is happy in the default state, but when it is time for a break, it shrinks into a small puddle. Once the user is back from the break, it comes back to life.

- **Sunrise (P4):** A painting that displays a utopian image (sunset) in its default state. As the time to take a break approaches, the painting slowly changes into a dystopian image (sad people, pictured at the bottom). Once a break is taken, the default state is presumed.

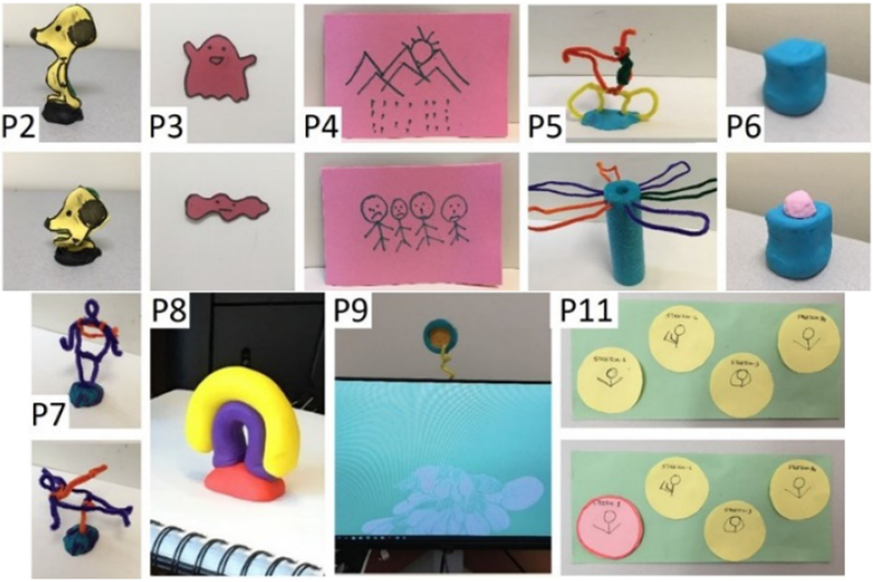

Fig. 3. Low-fidelity prototypes of tangible break reminders that participants with RSI designed for their workplace. Transformations towards the reminding state happen slowly from top to bottom figures in P2-P7, while P8 and P9 rotate, and P11 lights up.

- **Morphy (P5):** A desk toy that changes form from, e.g., a bicycle (top) into a lily (bottom), to give the user a new object to take care of each week. In each case the object has a default behaviour; wheels spinning for the bicycle and the petals blooming for the lily. When it is time to take a break, the wheel stops spinning for the bicycle and petals wither for the lily. When the user is back from the break, the default behaviour is resumed.
- **Luna (P6):** An abstract cyan coloured cylindrical object with a light bulb that emerges out slowly when it is time to take a break and fades in. Once the user is back from the break, it fades out and returns to its default state.
- **Superman (P7):** A desk toy figurine that stands upright in the default mode. When it is time to take a break, it moves to a flying position. When the user is back from the break, it is back to the standing position again.
- **Turbo (P8):** A bright-coloured desk toy designed as an abstract representation of a human. In the default state, it is constantly rotating along a central axis. When it is time to take a break, the rotation slowly stops. Once, the user is back from the break, it starts rotating again.

- **ShyFrame (P9):** A tiny frame with a pleasant scenery (e.g., a picture of the ocean) that hides behind the desk monitor. When it is time to take a break, it slowly moves up to become visible to the user reminding them of positive things. Once the user is back from the break, it goes behind the screen again.
- **Arcade (P11)**: A console board with circular buttons representing four stretches. When it is time to take a break, one button lights up, suggesting doing that particular stretch. When the user performs it, they hit the button and the light goes off.

4 Findings

We discuss the results of our thematic analysis drawing on the data from the three activities with 11 participants with RSI. Our choice to use qualitative user interviews, design critiques and ideation as evaluation mechanisms means that the emphasis of our results is less on our "design concepts" and more on a critical reflection of what this user population needs. Accordingly, our themes (i.e. subheadings in this section) unpack the users' own design, preferences and challenges, thereby exploring how they imagine interactive everyday objects can support their well-being while not disrupting their work productivity.

4.1 Ubiquity and Calmness

F1: Disruption and Social Barriers. During the interviews, participants expressed the challenges and barriers to adopt break-reminding digital apps. S*ocial barriers*, which are issues related to having a group of people working in a social environment, prevented them from setting audible notifications on their mobile phones at the workplace and thus remembering to take frequent breaks. *Workflow barriers*, which are issues relating to their set of tasks to accomplish, were identified as the biggest barrier to taking regular breaks (N = 9) as desktops or mobile apps notifications significantly disrupted their tasks in-hand and negatively affected their work productivity.

While several participants (N = 4) reported using notifications at some point to incorporate more breaks and stretching during their workday, only one was actively using it. They used it for awareness during the day rather than using every reminder to take a break. Others (N = 3) had used it in the past but stopped because it was disruptive to the work and felt too frequent. This aversion to notifications was also due to their existing numerous notifications. P3 said: "*overtime I might get desensitized to it too… I would just ignore it and also be annoyed*", while P8 revealed: "*I already have enough notifications to deal with and I don't want them to interfere with my work but something subtle in the watch maybe, only for that purpose.*"

On this basis, participants preferred *probe2* over *probe1*, critiquing the latter to be disruptive. While participants acknowledged the advantage of good visibility of shape-changing actuation in the mouse, they perceived it intrusive and potentially annoying in the middle of work (N = 9). Moreover, all of their designs were not work-related objects (e.g., mouse/pad, keyboard), but practically decorative desk toys.

F2: Peripheral and Ambient. Participants clearly wanted their break reminders to be in the background of their perceived environment and not demanding much focus. They designed their concept interfaces as part of their workspace i.e., toys, décor or objects on the desk, wall or board. In this sense, interactive objects are in the user's periphery, rather than constantly at the centre of their attention, shifting to their focus only when needed and when appropriate. Such ambient and calm interaction empowers users with selective peripheral focus e.g. "*I want to look at it when I lose my attention*" (P3) and "*it gives something different but without forcing you*" (P11). This aligns with the literature on ambient displays.

F3: Slow Interaction. In addition to preferring an object that is ubiquitously part of the surrounding environment, participants also described their designs as *slow*. This does not only support the previous findings in this theme that interfaces are desired to be calm, ubiquitous and in the user's periphery, but also aligns well with recent research on designing for slowness as an interactive value [35, 36]. For example, P9 designed the *ShyFrame* as hidden from sight, but slowly moves up over time to become completely visible when a break time is due. Even with the spinning *Turbo*, P8 designed it so that the motion is (dis)continued in the periphery and only becomes noticeable as it "*slowly stops*". This notion of (relative) longevity that users desire is contrary to most current technologies that are instant and immediate.

4.2 User Engagement

F4: Playfulness. Most of our participants (N = 8) designed "*desk toys"* as their desired tangible break reminders, for playfulness and multifunctionality (discussed in F10). Playful interaction can be thus employed in designing interactive everyday things as a means of supporting user engagement. What intensifies such engagement is having a delightful design that resonates with personal appeal of toys. For instance, P2 thought their *Snoopy* was "*cute*", P8 made theirs in bright colours to be "*cheerful*". Nevertheless, even abstract designs can have a sense of enjoyment in engaging with them, such as how P11 described the satisfaction of hitting the buttons and how this "*sparks joy*".

F5: Emotional Engagement. Many designed for a relationship between the object and themselves. Several participants (N = 6) mentioned that the need for emotional connection with the object was important to listen to its suggestion without being annoyed. Some also mentioned relatability with the actuation as a determinant factor for emotional engagement with the interface. For example, work-related objects such as *probe1* (i.e., the springy mouse) were harder to relate to, compared to an anthropomorphic object such as *probe2* (i.e., the wilting flower). They described animating objects as feeling happy, sad, in pain or mirroring the user's own RSI state.

F6: Motivation and Care-Giving. Designing something to take care of reoccurred in the data, even with non-animated shape-changing designs. Several participants (N = 7) mentioned the emotional connection and persuasion capability of the object as an important factor to effectively listen to the object when it asks them to take a break. For participants, taking care of something meant taking care of themselves and gave them a motivational objective. This use of caregiving in design is emphasized in anthropomorphic objects such as "*a character or a pet I could take care of, I would care a little bit more*" (P3). However, P5 was worried about *probe2* and the rate of interaction asking "*How often would it die?*". Even, P5 who designed a morphing figure explained that it had a value-based concept of caring for their environment as bikes are eco-friendly: "*gotta keep the bike spinning*".

4.3 Shape-Change and Transformation

F7: Self-awareness. Some users tied up shape-changing interaction with self-reflection. They designed for self-awareness through the shape-shift of their objects. Such transformation included positive feedback as a reinforcement to taking more breaks. These included objects reflecting *self-care* by physicalizing the change, emoting positivity (P5, P6, P7, P9) and enabling the feeling of accomplishment (P11). Participants used both negative and positive scenarios to "making *that connection with taking care of yourself, taking out the time, stretching*" (P8).

F8: Visualizing the Consequences. Negative transformation was used in which the state of the object visualizes and reflects one's state -in proxy- or a representation of the body to remind them of the effects of prolonged sitting. E.g. P2, P3 and P8 made their objects deflate, degrade or break down when their bodies are in need for stretching. P4 depicted a positive imagery that turns into a negative scene explaining this is: "*to see the journey… assuming the longer I work the more I am hurting my back*".

F9: Fading Novelty. Participants pointed out one limitation of actuating break reminders was the wear off of the novelty effect. They expressed concerns around progressive boredom. Some participants suggested designs to overcome this challenge by varying the shape-shifting interaction or changing the object every while as their anti-novelty strategy. Others believed caregiving interaction will turn into a daily healthy routine: "*because once you do it for whatever number of days it becomes a habit*" (P5). Others suggested personalization and customization of their desk objects as their strategy to renew their visceral qualities (P9).

4.4 Design Qualities

F10: Practical Constraints and Multifunctionality. A major constraint was the presence of a plethora of work objects that could obliterate the visibility of the actuating break reminder. Participants frequently expressed aversion to placing more objects on the desks and wanted to utilize their favourite pre-existing objects as multifunctional elements that would do more. The social acceptability of such objects varied per participants: for instance, users in more conservative workspaces were hesitant to have a playful object on the desk. For example, P4 designed an abstract object to avoid attention but still personalized it in their **favourite** colour.

F11: Physical Dimensions. Due to limited desk space, a crucial aspect of shape-changing break reminders in the workplace is the scale of the object. Most participants leaned towards making their break reminders by designing them smaller in size (N = 8). Although we introduced our two probes in real-world 1:1 scale, participants suggested they would adopt probe2 if it was in half the size or less. This led to making their object small so that it can sit close to the visual space of the user but is not big enough to be intrusive. Other strategies included pinning the device on the wall or board (P3, P11) or attaching it to the back of the monitor (P9). This included the need for the object to not only require less desk space (N = 7), but also to be multifunctional (e.g., a clock that is also a break reminder), and to be in the visual space of the user.

F12: Aesthetic Values. Other physical attributes of the object such as appearance, colour and texture were also discussed by participants. Three participants (P4, P8, P9) discussed the possibility and importance of making the object easy to personalize not just to them but also considering other people's preferences. Participants used both abstraction and anthropomorphism to alter the appearance of their objects. Aesthetic qualities varied from animate characteristics like changing emotions of the object when the user returned from the break (P2, P3, P4), resuming the state of motion of the object (P2, P3, P5, P7, P8) to inanimate characteristics like change in peripheral visibility of the object using light or position of the object (P6, P9, P11).

F13: Personal Preference. We found a correlation between the personal preference of the participant and the design of their break reminding object. For example, P2 chose to have snoopy as the break reminder because it was their favourite character; P3 made an animated object and we observed that they owned a few personal objects depicting similar animated characters; P9 made a small frame with the picture of the ocean because they grew up next to the ocean and it reminded them of home.

5 Prototyping

To enrich the evaluation of our co-designing process, we developed fully-interactive implementations of the design concepts, drawing inspiration from participants' designs and the lessons learnt from our findings (F1–F13). We programmed the prototypes to actuate every 60 min as recommended by healthcare practitioners to reduce RSI symptoms [9]. Our goal is to demonstrate how the experiential expectations and needs of users can be incorporated in the design of things they would want to live with.

We categorized user designs into three categories: 2D planer frames (P4, P9, P11), 3D abstract objects (P5, P6, P8) and animated toys (P2, P3, P7). Then, we developed one from each category (P2, P6, P9) as examples of everyday objects using non-focus demanding, silent, subtle and slow interactive electronics. Emotional engagement is employed through playfulness and caregiving. Their actuation reflects state-change through both positive and negative notions. Finally, the aesthetic qualities consider their practical concerns and reflect their personal and aesthetic preferences. Study 2 will provide an assessment of the prototypes through reflections.

5.1 Snoopy

As an example of the anthropomorphic preference (F4) of users, we prototyped the design of P2, an actuating desk toy as a break reminder (Fig. 4). We stuffed a 10 cm high snoopy plush toy with Shape-Memory Alloy (SMA) springs connected to a MOSFET powered Arduino microcontroller, hidden in the base. Snoopy collapses down when it is time for a break silently and slowly every 60 min.

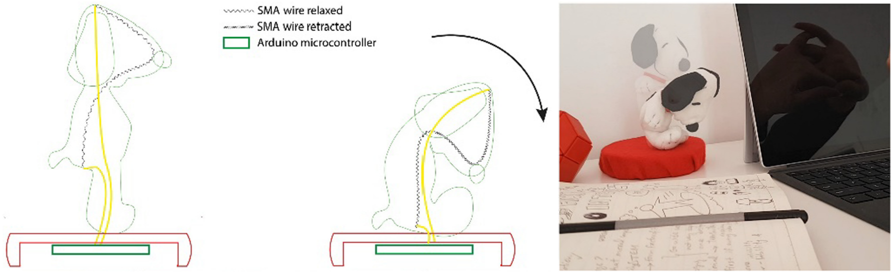

Fig. 4. Snoopy: the interactive desk break-reminder from P2 is a fabric toy that collapses when it is time for a break and deforms its body using sewn SMA wires.

Our goal was to control its shape-change without motors to keep free of audible notifications (F1), due to social barriers in shared workplace. We used SMA wires to deform the body of this object was to make it silent (F1), slow (F3) and subtle, moving in their periphery but not rather distracting (F2). We purposely used a plush snoopy toy rather than a rigid-material model to utilize its softness, furry texture and material affordance in supporting its playfulness (F4), emotional engagement (F5) and caregiving motivation (F6) that would have been somewhat lost or reduced had it been a 2D or rigid figurine. Moreover, the organic twist deformation of the body caused by the fabric stitched with SMA wires accounts to the negative impact of continuous work without breaks and visualizes its entangled consequence (F8).

As much as the creating a shape-changing Snoopy might seem frivolous, more than half of our participants expressed the need for an emotional connection with the object, to strengthen their chances of listening to its suggestion without being annoyed (F5). P2—who already had a Snoopy toy on their desk—wanted to repurpose it to serve as their break-reminder (F10). The incorporation of interactive technology within users' favourite objects reflects and supports their personal preference (F13). We housed the electronics underneath Snoopy—not beside—to save some desk space (F10).

5.2 ShyFrame

As an example of planer desk frames, we prototyped the design of P9, a monitor-mount frame-like break-reminder. To allow the ShyFrame to rotate, appear and hide silently (F1) and slowly (F3) behind the digital display, we used a silent TOKI RC1 motor made of SMA wire. To maintain scale, we used the smallest off-the-shelf Adafruit Trinket 5V mini microcontroller (F11) to control the motor with a USB cable from the user's computer. The challenge of the ShyFrame was to use light-weight materials that can be easily mounted behind the monitor with a magnet and can be moved by the low pull-force of the SMA motor every 60 min (Fig. 5).

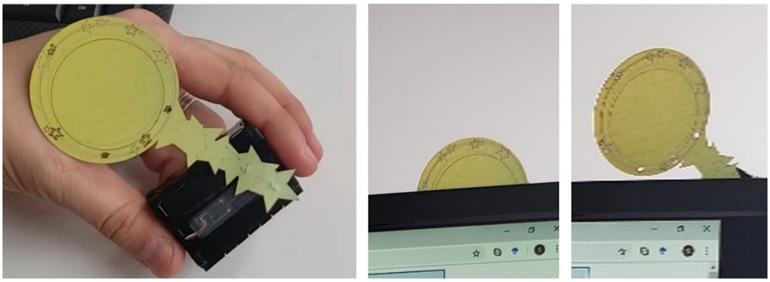

Fig. 5. ShyFrame: the monitor-mount shape-changing break-reminder of P9 saves scarce desk space. It hides behind the monitor and rotates using a silent SMA motor to reveal when it is time for the working user to take a break.

We specifically chose colourful cardboard similar to the user's design (F13) to support aesthetic values (F12) and reflect the *gradual* shape-shifting behaviour (F3), as opposed to a solid colour material. We then laser-cut the material with a design of a star-shaped frame and arm to support delightfulness (F4) and express positivity (F7).

The localized actuation meant that (almost) only the user on this desk could take notice of the slow motion. The choice of the SMA motor meant that the shape-change is not only silent (unlike the sound-producing servo-motors), but is also rotational, moving in a controlled angular path. Although it is using the monitor as its space to consume no desk space (F10), it is not hindering their work productivity (F2) as other desktop break-reminding applications that freeze the monitor for instance.

5.3 Luna

As an example of 3D abstract desk objects, we prototyped the design of P6, a physical artifact that has an emerging light on top. We used a clear flexible resin to 3D print the cylindrical object in dimensions 10 × 10 cm. We used a servo motor using a gear and a shaft to control the height of the illuminating top section. Inside the body of Luna, an Adafruit Metro Mini microcontroller controls both the motion and an RGB LED for the light. We used a translucent breadboard to avoid obscuring the light and placed all electronic components inside with a connected USB cable to powers the circuit from the user's computer (Fig. 6). The light started from blue and transitioning very subtly to green, yellow, then red (time to take action, i.e., a break) every 60 min.

The light reflection design decisions (using clear acrylic, clear resin, minimal-sized microcontrollers and clear breadboard) to make it calmer (F1), ambient and less distracting (F2). Additionally, the slow (F3) gradual RGB degrade defused the LED light, supporting self-reflection by visualizing the consequences (F8) and physicalizing the state-change (F7). The red light is intentionally not alerting but is still soft, ambient and diffused by the thickness of the 3D design, as interactive break-reminders should not

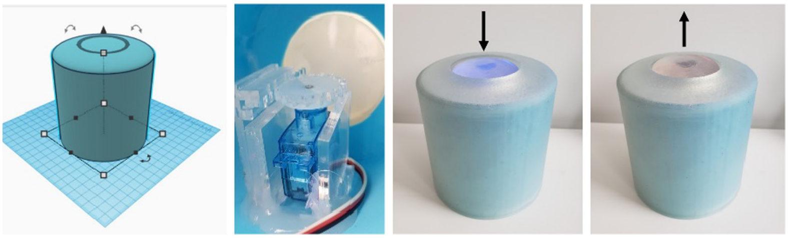

Fig. 6. Luna: 3D-printed shape-changing desk object as P6's design with an emerging light that moves up slowly and changes its ambient light as break time approaches (Color figure online).

standout (F2), a bright emissive flashing light would have been too focus-demanding. Also, we chose light colours to give the design both emotional associations (F5) and dynamic aesthetics (F12). Moreover, the slow motion (F3) of the "emerging" top part (at a rate of x mm/sec) does not require immediate attention but allows the user to shift their focus only when needed and when appropriate.

We incorporated P6's personal preference (F13) of the abstract cylindrical design with slight curves in the 3D model and the cyan colour using a 1 mm flexible foam sheet lining layer for the aesthetic appearance (F12). However, we note that this is an added object that takes desk space (F10, F11), compared to the other two prototypes.

6 Study 2: User Reflection

Taking our prototypes back to users who designed them, we reinterviewed P2, P6 and P9 to gather their impressions about our implementation of their prototype design, in the form of design crits. We held a 1-h virtual interview with each participant in the summer of 2020. Participants signed consent forms electronically and received $30 CAN eGift Cards as a compensation for their time. Three participants (1F, 2M) are in their 30s, all working around 8 h/day on computer desks (P2 and P9 in administration while P6 in the software industry).

After a brief introduction, we showed the 11 low-fidelity designed concepts and discussed their perceptions. Then, we demonstrated the actuation of the three high-fidelity prototypes built through a video and asked open-ended reflective questions. We audio-recorded the interviews and transcribed them for an iterative process of Thematic Analysis. We report our qualitative analysis by reporting cross-reflections (reflections of participants regarding the prototypes they did not design), and self-reflections (reflections on the implemented prototype designed by them).

6.1 Cross-Reflection

As we showed participants the other low-fidelity designs from Study 1, they reflected individually on other designs ideated by the rest of the participants. The predominance of desk toys in the Study 1 ideas generated particular reflections. They described Actuating desk toys as objects that "*play a role*" (P6), trigger laugh/smile (P9), serves decorative purposes and provides an "*emotional connection*" (P2). For instance, all participants described *Snoopy* as "cute" (F4). P6 explained that "*people need to like what they see on the desks for the object to have the right to remain among the objects that are important for everyday*" (F12). P2 also described this as "*you're keeping something there and you want to keep it happy. That will be helpful to… helping me in that way, I'm taking breaks and happiness, not like 'Oh, I have to break'… [Apps are] dictating to you, but these things are not dictating*" (F5).

Cross-reflection also touched on anthropomorphism—even for abstract objects- and caregiving as a resource for motivation (F6). P6 described Luna as "*a companion*" and P2 described Turbo "*like a virtual pet, you want to keep it alive*" and stated that "*there is kind of a reward… you made him happy or you saved him*" (F7). Alternatively, they also described care-receiving as a value of the ShyFrame "*it feels like it's a person… maybe it's your parent, who's coming out regularly, maybe somebody else that used to have played a role in your life, take care of you, reminding you, and you cannot be impatient to them*" (P6).

Participants also reflected on the variation in designs to meet different preferences (F13) and discussed how the favoured personalization features of such tangible break reminders are different from software customization of apps. For example, P2 said about the Turbo: "*it makes me feel that this thing is, uh, stopped because of me. So I should go away and come back so that it starts spinning again*". However, some participants refrained from negative transformation (F8) while others noted the potential wear of novelty over time and procrastination (F9) including examples of the alarm clock's snooze button (P2, P6).

Evident in the data is the divergence of personal preference and that there is no one-size-fits-all design (F13). For example, P6 reflected on the *ShyFrame* (designed by P9) saying, "*This shy frame is very interesting. I think it's very cute,*" (F4) while P2 stated, "*Personally, I didn't like that… something rising from my screen… It's more to me, like a distraction came up.*" Similarly, P2 reflected on Turbo (designed by P8) "*it will make me notice how it stopped… It's a good emotional connection*" (F5), while P9 said that it's "*so distracting for me… for me, it would be the other way around, like I would like it to be still and then just start to move when I need to take a break*". Still, all participants expressed their interest in Luna and its design qualities.

6.2 Self-reflection

We asked each participant to reflect on the high-fidelity prototype based on their idea. P2 (who designed *Snoopy*) confirmed its size (F11) and actuation (F7) that in its physicalized form is their "*ideal thing*" and that "*The size's small. So that's really convenient to keep it. It's like a showpiece as well.*" He also highlighted the fact that it does not hide or disappear from the periphery (F2) but "*is always there. So it's kind of a constant reminder*". He also suggested some aesthetic and emotional actuations (F7, F12): "*there's more room to play with the eyes. That feature can be applicable to all these prototypes, which have a character like Snoopy or that toy or others.*"

P6 (who designed Luna) praised the prototype saying, "*I still have the same type of excitement when I imagined that object a while ago… I think you guys captured very loyally… with a lot of detail, it's like a very close, super close to my description.*" (F5). P6 praised the silent (F1) and slow (F3) movement as an additional user feedback (F7) on top of the light that conveys further information through its colour-change. P6 suggested some design features to be enhanced including thinner material and giving user-control over light brightness to accommodate for ambient conditions.

Finally, P9 (who designed ShyFrame) reflected on the prototype with delight, favouring it over all other designs describing its playfulness as "*something cute, that you could personalize*" (F4, F13) and size (F11). She confirmed the location (F10) and practicality of being monitor-mount to be ideal to grab her attention in her area of periphery (F2). She also elaborated on her positive thoughts of family or adventure photos (F5, F13) to be put in that frame, explaining "*when I see it I need to stop and I need to stretch… the fact that you can put a goal, put something really personal.*" P9 recommended that the actuation to be in an exponential motion and start slow (F3) rather than linear with consistent speed. She also suggested some aesthetic changes (F12) including material qualities and polka dots decoration instead of stars.

7 Discussion

Through our 2 user studies with 11 participants who all live with Repetitive Strain Injury (RSI), we learnt about their daily challenges with break reminders. Most people avoid digital alerts and instead use physical objects as reminders to help them adopt a certain behaviour. By engaging them in user-centred design to make tangible break-reminders and analyzing what they created, we were able to draw appropriated design decisions for implementing high-fidelity tangible break-reminders that unfold their needs. Taking these implemented interactive prototypes back to our participants in Study 2 enabled deeper understanding and insight on their design critique reflection. Our hope is that this research would inspire designers engaging with actuating physical interfaces and elevate the discussion around tensions between what we as researchers create as prototypes and what users often ideate for themselves.

To deepen our analysis and discussion our findings, we collated the use of the 13 findings as implemented in the prototypes and correlated them with findings discussed in the second study, through self- and cross-reflections. Table 1 highlights that some findings were implemented and noticed by each participant (e.g., F3), while others were unique to some prototypes. This supports our choices of building three different prototypes. For instance, we find it interesting that while we designed Snoopy and Luna to produce an emotional engagement (F5), the participant who designed the concept of ShyFrame interpreted our prototype as being emotionally engaging. This table also clearly highlights that the finding of fading novelty was not integrated in the designed or discussed in the second study. A long term, in the wild study measuring use and engagement is necessary to address and assess this initial finding.

Our findings can be grouped as challenges (F1, F9, F11), preferences (F2, F3, F12, F13), and unspoken desires (F4, F5, F8) such as self-care (F6, F7). Overall, our participants found desk toys to be interesting as break-reminders (similar to BreakAway [12]) as opposed to computer-related objects (such as keyboard, mouse and pad). Limited desk space, hot-desking and home offices are a current reality that requires relatively small-sized interfaces. Participants also wanted designers to consider wall or monitor mounted devices: while the idea of monitor-mounted artifacts is not new [33], it could be

Table 1. Summary of findings implemented in the 3 prototypes. The circle (●) indicates a finding used in the prototype design (PD), the black square (■) when discussed in the self-reflection (SR), and the white square (□) when discussed in the cross-reflections (CR).

		Snoopy			ShyFrame			Luna		
		PD	SR	CR	PD	SR	CR	PD	SR	CR
F1	Disruption and social barriers	●	■		●	■		●	■	□
F2	Periphery and ambience	●	■	□	●	■	□	●	■	
F3	Slow interaction	●	■		●	■		●	■	
F4	Playfulness	●	■	□	●	■	□			□
F5	Emotional engagement	●	■	□		■		●	■	
F6	Motivation and care-giving	●	■			■	□			□
F7	Self-awareness	●	■		●	■	□	●	■	
F8	Visualizing consequences	●		□				●		
F9	Fading novelty			□	●				■	
F10	Constraints and multifunction	●	■	□	●	■			■	□
F11	Physical dimensions	●	■		●	■			■	
F12	Aesthetic qualities		■		●	■		●	■	□
F13	Personalization	●	■	□	●	■	□	●	■	□

further exploited by the HCI community. We also do note that two participants were not engaged with physical shape change, which strengthens the need for personalized break reminders (F13), whether physical or digital. Other aesthetic and design quality considerations should be considered by workplace designers and researchers to support user adoption of prototypes in situated deployments in shared spaces to avoid possible social barriers, particularly of importance to people who require break reminders because of their RSI. We acknowledge that some findings may feel contradictory: creating a playful desk toy when none exists opposes F4 and F10. However, these tradeoffs are part of designers' reflections when creating new objects or interactions [57].

Our paper presents first-hand lessons learned from people with RSI on how they want to design their break-reminders. The technical implementation of the interaction would not be innovative as there is enough knowledge in the community on how to build it differently if needed. Our focus on the 'design' stems from the research gap found where no prior work has involved people with RSI in designing their own break-reminders, yielding unprecedented insight and deeper knowledge on novel designs that people could benefit from away from mainstream and mass-produced apps and technologies.

Finally, we acknowledge the limitations of interviews in Study 2, both in their reflective nature as well as sample size, and plan for in-situ long-term deployments. As with such study design, our work is limited to the insights of our participants. Perhaps a richer dataset could have emerged from the involvement of RSI experts. However, our goal was not to evaluate between an approach based on the participatory design and another based on the involvement of more expert researchers, which is interesting but is out of scope. Our findings can serve as recommendations that designers may take into account when creating new break reminders for people with disabilities. Although some might perceive these findings as generic to claim relevance to RSI, our approach inherently unfolds a counter-argument. The quality and value of inclusive design lie in putting people with symptoms and their preferences in the centre of the design process and sincerely designing *'with'* them. People increasingly do not want to look or feel alienated due to any symptoms they are living with. Therefore, such inclusivity-led research will support designing things they want to live with instead of gadgets, devices and dongles that are often designed '*for'* them [58, 59].

8 Conclusion

This paper explores the opportunity of designing tangible everyday objects that can help users mitigate the impact of repetitive strain injury, by reminding them of taking breaks, maintaining good posture and incorporate regular movement during work. Unlike current technology that relies on immediate notifications to achieve this, slow and calm interactive physical objects on their desks can inform users without disrupting their work productivity. We engaged people living with RSI to design their own tangible break-reminders and interviewed each of them to gain deeper knowledge of their challenges and aspirations. We implemented a representative subset of the design concepts, then conducted a second study with the same participants to allow them to reflect on their designs. Through our method of sandwiching the prototyping phase between two rigorous user studies, the design rationale of each prototype we made direct links to the findings of the first study.

Our study findings demonstrated how the interactive everyday objects that users wanted were not focused solely on the state transformation but included notions such as: the emotional engagement of cute and playful objects; the social barriers of owning some designs in a shared environment; visualizing the consequences of negative behaviour; motivating interaction and continuous use through values such as caregiving; and to the value of aesthetic design qualities. Future work will focus on an in-situ deployment of the prototypes to investigate the short term and long term adaption and effects of the tangible objects as reminders for people with RSI. We also look forward to expanding the concept of tangible object, to consider break reminders through the furniture itself, by studying shape-changing desks [39, 43, 60].

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