Shape-Changing Break Reminders for People with Repetitive Strain Injury

by

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Abstract

People with Repetitive Strain Injury (RSI) performing computer work for more than 4-5 hours/day are recommended to take microbreaks (30 sec to 1 min) every hour to reduce their symptoms. This is difficult during work as other things occupy their mind. While notifications can be used as reminders, they adversely impact the affective state and productivity of the user. Shape-changing devices demonstrate potential as they can provide passive awareness. We conducted an ideation session with HCI professionals to identify opportunities for shape-changing break reminders and interactive sessions with people with RSI. We found that the participants struggled to take enough breaks, found notifications inadequate, and modified their primary task to incorporate movement. They demonstrated an aversion to disruption, were receptive to shape-changing break reminders, and desired to emotionally engage with them. This demonstrates the potential of shape-changing break reminders as can be ambient and engender emotions through physical transformation.

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Chapter 1: Introduction

1.1 Motivation

A greater number of people work at the computer as our society continuously moves towards digitization. Computer-related work is a major contributor to a sedentary lifestyle and exacerbates work-related injuries [14,56]. These injuries are broadly categorized as Repetitive Strain Injury (RSI), which has become a prevalent health issue. In Canada, more than 10% of the population has RSI according to a study conducted in 2000 [51]. These injuries cause nerve, tissues, and tendon damage affecting mobility in hands, shoulder, wrists, and back, limiting normal activity in people and affecting their physical and psychological well-being [48]. RSI is commonly caused by poor ergonomics of devices, repetitive motions, prolonged sitting, and bad posture [56]. In addition lack of attention to ergonomics, psychosocial factors like anxiety [2,63], mental exhaustion [27], social support [48], work organization [17], and time pressure [8] also increase the risk of RSI, and aggravate the symptoms.

To mitigate the impact of these causes, it is recommended to maintain good posture and incorporate regular movement at work [37,53]. Microbreaks (10 to 60 seconds) reduce the load on activated muscles and provide a mental break that increases productivity [37]. Despite the two-fold benefits of microbreaks, people find it hard to follow a regimented break routine because it disrupts workflow. Notifications (such as time based desktop and phone reminders) can be used to help users take breaks, but they are often ill-timed and not aware of the user's natural work pause pattern [74]. While the delivery timing of these notification can be optimized based on the individual work habits, they are still not capable of gauging the changing context of the user. For example, if the user just returned from a break, or if the user is currently in the middle of a crucial task. In addition to that, such interruptions exacerbate stress and productivity [2]. Thus, there is a need for a break reminder that regards the workflow of the user and provides passive awareness while being conducive to work and productivity.

Calm technology demonstrates the ability to switch from the user's periphery to the center, at the user's accord [43,66,69]. They do so by slow and quiet changes in the user's periphery. They have been implemented in the literature by integrating light, audio, or ambient motion through shape change in the user's periphery [16,43,66]. Tangible user interfaces (TUI) are physical objects that embody digital information [40]. By integrating with or augmenting the physical objects present in the environment and can provide ambient feedback by using light, audio, and slow motion as peripheral feedback. Shape-changing capabilities can be a compelling medium worth exploring in such contexts: in addition to successfully providing peripheral feedback through change in physical factors (such as orientation, form, volume, and texture), shape-changing devices can offer more dimensions such as expressiveness and multiple affordances to communicating information [1].

1.2 Shape-Changing Devices as Break Reminders

Shape-changing devices are advanced tangible user interfaces that can undergo physical transformation using electrical stimuli, without any external manipulation [67]. Such physical transformation in form, volume, texture, and viscosity offer new methods of input and output interaction. These transformations are used with a functional (for example, use dynamic affordances, or communicate information) and hedonic (for example, aesthetic appreciation, or to engender emotion) purpose in the literature.

For the functional purpose of communicating information, slow transformations are used for non-intrusive, peripheral feedback [31,43]. These slow changes facilitate noticeable change over a long period of time without catching the sudden attention of the user as in the case of a sudden transformation. Their ability to communicate information through providing passive awareness to the user using subtle change in physical form demonstrates their potential as a break reminder in the context of work. As the user can look at it when they lose focus from their primary task, it is conducive to work and productivity.

In addition to the functional potential of ambient information communication, shape change also has the hedonic potential of engendering emotions [69] and aesthetic appreciation [21]. In case of a tangible break reminder that exists in the workplace of the user, we can use this hedonic potential to design a device that delights the user merely by its presence.

To understand how to effectively use these functional and hedonic potential of shape-changing devices in the context of a break reminder, it is first important to understand the terms of acceptance of these devices. However, to the best of our knowledge, no work focuses on the perspective and context of the users with RSI.

1.3 Research Questions

The main research question guiding this thesis is

- What is the potential of shape-changing devices as a break reminder system for people who have repetitive strain injury?

To answer this question, our research objectives are two-fold:

1. Understanding the work context in which RSI occurs, the coping strategies, and challenges faced by people with these problems.
2. Translating initial impressions about the shape-changing break reminder system and the desires of the users into design guidelines.

Following our research objectives, we conducted two studies to investigate the potential of shape-changing break reminders for people who have RSI. In the first study, we conducted an ideation session with 8 Human-Computer Interaction (HCI) professionals (students and researchers). We conducted this session to understand the design space with people who are familiar with these concepts and to use the insights from this study to inform later sessions with end users, who would typically find these concepts novel. We facilitate generating plenty of ideas that are still rooted in the research, by creating a visual representation of the ideation space in form of a graph. In the session, the participants generate ideas and position them on the graph, thus positioning them in the design space. At the end of the session, we cluster these ideas and divide the design space in 6 high level categories. We used these categories to identify areas of intervention in the design space and to position the design probes used in the following study, with end users.

For our second study, we conducted interactive sessions with people with RSI in the context of their work environment. We had 11 people who reported chronic strain in their arms, shoulders, wrists, or back. Each session had three consecutive phases: 1) the Interview, where we asked them questions about their coping strategies and pain points of working with RSI. 2) the Design Critique, where we introduced design probes positioned in specific categories identified in the first study, for initial impressions, and 3) the

Participatory Design Session to capture tacit knowledge and unspoken needs and desires of people with RSI from a break reminder. We audio recorded the session, transcribed the recording, and analyzed the transcribe audio of the three phases separately using manual thematic coding [70] to identify recurring codes and group them into higher level themes. Our results show that participants were highly aware of the health behavior to be incorporated to reduce their symptoms and often struggled to do so, due to workflow and lack of technological support. They expressed a strong aversion to being disrupted by the future technology (shape-changing break reminder), suggesting the need for the break reminder to be ambient. In addition to supporting their functional and pragmatic needs, participants demonstrated a preference for emotionally engaging with the tangible break reminder and desired for it to be more than a functional artefact sitting in their work place.

1.4 Contributions

To the best of our knowledge, people with RSI have not been included in user studies related to break reminders. This demographic can bring new insights to the study of break reminders. They perhaps have more experience of trying to incorporate breaks during work as a part of incorporating 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 behavior such as taking rest and stretch breaks. Through the interactive session with 11 participants with RSI, we make the following contributions. We identify:

- Challenges faced by people with RSI while trying to incorporate health behavior at work.

- Insights and impressions of shape-changing break reminders from people with RSI.
- Design guidelines for break reminders for the workplace.

To the best of our knowledge this is the first study in investigating shape-changing devices from an ethnographic approach capturing the context and latent needs of the users to formulate a design guideline.

1.5 Thesis Outline

The thesis is organized in 6 chapters. In Chapter 2, we discuss the literature on causes and prevention of RSI, interruptions at work, tangible user interface and shape-changing technology, and participatory design. In Chapter 3, we present the methodology and results of the ideation session conducted with 8 HCI professionals. In Chapter 4, we present the methodology and results of an interactive session conducted with 11 people with RSI. In Chapter 5, we present design recommendations based on the findings from the study conducted in Chapter 4 and finally we present the conclusion in Chapter 6.

Chapter 2: Background

To understand the challenges faced by people with RSI at work, to engage with them, and identify their needs from a break reminder system, we reviewed prior work on repetitive strain injury, interruptions at work, calm technologies, and participatory design.

2.1 Repetitive Strain Injury

In this section we discuss the prevalence, causes, and symptoms of Repetitive Strain Injury (RSI) followed by the work done in HCI to address computer related RSI at work.

2.1.1 Causes and Symptoms of RSI

According to the 2000 General Social Survey conducted in Canada with approximately 25,000 people [51], the proportion of workers using a computer at their main job has risen from 33% in 1989 to 57% in 2000. Additionally, 80% of these workers used the computer every day. With the dramatic rise of computer usage in the past few decades, RSI affected almost 2 million people in Canada in 2000, making it a major public health concern [90].

Work-related injuries can be an injury either caused or exacerbated by the activities performed during work [14]. Prior work shows that more than 10 hours of mouse and 15 hours of keyboard usage per week increases the risk of pain in the forearms [46]. Additionally, computer usage also leads to sedentary behavior and awkward posture that increases the risk of strain in shoulders and back [14]. The pain is often debilitating, limiting normal activity in people, affecting their psychological and physical well-being, and causing monetary damage as a result of lost working hours [48]. The symptoms of these work-related injuries are muscular and neurological inflammation in wrists, arm, shoulders, or back, generally termed as Repetitive Strain Injury [56].

While earlier work focuses on investigating the impact of repetitive movement, awkward posture, and lack of attention to ergonomics due to prolonged sitting and computer usage [28,46], more recent work demonstrates that this approach is perhaps oversimplified. Psychosocial factors like anxiety [2,63], mental exhaustion [27], social support [48], work organization [17], and time pressure [8] also exacerbate RSI at work.

2.1.2 Prescribed Measures of Prevention of RSI

Lack of attention to ergonomics of the work desk and devices is a major cause that exacerbates RSI symptoms [56]. The physical objects that the user is in contact with during work can facilitate good posture to mitigate and prevent the symptoms of RSI [56]. For example, the load on the muscular group activated during computer work reduces when various factors (like the height of the work desk and the chair, and physical form of the mouse and keyboard) change to facilitates a neutral position of the arms, wrists, shoulders, and back [53]. Their proven effectiveness in reducing RSI symptoms has led to the popularity of ergonomic devices in the market, for example, the vertical mouse, split keyboard, ergonomic chairs, and track ball mouse [91].

In addition to workplace ergonomics, 'health behavior' at work reduces and prevents the symptoms of RSI [24]. These include engaging in regular stretch and rest breaks and incorporating regular physical exercise. The effectiveness of stretch and rest breaks to reduce muscular load is well established in the literature [3,6,37,52]. Henning et al. [37] conducted a study at two work sites with 73 and 19 computer operators respectively. They found that hourly microbreaks (30 sec to 3 minutes) improved their legs, and feet comfort along with enhancing productivity. In a similar study, McLean at. al. [52] randomly assigned participants into three groups. Using reminders, they asked each group to take approximately 30-second-long microbreaks in one of the three conditions: at their own discretion, at 20 minutes, or at 40-minute intervals. They found that microbreaks showed improvement in the comfort in all muscle groups that were studied, particularly at a frequency of 20 minutes, without any detrimental effect on productivity during the experiment. In addition to providing relaxation to muscle strain causes by sitting and usage of devices, microbreaks also reduced the mental strain which activates the same muscle group as computer usage [27]. This demonstrates the usefulness of incorporating 'health behavior' in addition to improving the workplace ergonomics in preventing and reducing the symptoms of RSI.

2.1.3 HCI and RSI at Work

The strong research evidence on the effectiveness of microbreaks has led to the rise of many computer and web-based break reminder systems (e.g., [92,93]). These are time-based reminders that allow the user to customize the duration of work and pause. They usually notify the user through visual or auditory cues, such as pop-up notifications and sound alerts. While these break reminders can be useful to provide awareness to the users, these regimented breaks are a type of interruptions that increase task time, error rates, and anxiety in users [30].

Several works in the field of HCI present non-traditional break reminder to reduce sedentary behavior at work. In Superbreak, Morris et al. [54] added interactivity to regular breaks by giving 16 participants the option to choose between active and passive breaks. The intent of an active break was to give the user an option to do something that can enhance the effectiveness of the break. For active breaks, they could use physical movement to both play a vision-based game or read a document. In passive breaks, they could sit and watch a video. They found that 85% of the users preferred Superbreak over traditional break reminders and users generally preferred interactive breaks. However, they discuss that the regimented scheduling of the breaks was a problem as breaks were often suggested at inadequate times.

To address the inadequacy of intrusive break reminders, in BreakAway (Figure 1),

Figure 1: BreakAway in upright position [41]

Jafarinaimi et al. [41] introduces a sculpture that sits in the peripheral vision of the user. It tracks the user's sitting duration and slouches through a change in physical form to suggest the user gets up and takes a break. They found that users took more breaks around the time that the object was slouched suggesting the effectiveness of persuasion over intrusion to support rest and stretch breaks during work.

Few other works use persuasive but intrusive method to reduce sedentary behavior at work, In SitCoach [20], Dantzig et al. sends persuasive messages to users to advise them to take a break. They found that users who received persuasive messages took more breaks than users who did not. Reinforcing the effectiveness of persuasive technologies as break reminders.

2.2 Interruptions at Work

The basic feature of any break reminder is to intervene work to remind the user that it is time to move. This means it is important to understand the cost of interruption on work and well-being. In this section, we discuss prior work on the cost of interruption on work, followed by works on non-intrusive notification systems such as calm technologies and shape-changing devices.

2.2.1 The Cost of Interruption on Work and Well-being

Prior work investigates the cost of immediate interruption on work and productivity [2,19,38]. Interruptions in the form of phone and desktop notification do not regard the user's primary tasks, increase task time, and perceived task load [2]. This happens primarily because users take longer to resume the primary task after being interrupted [38]. In a diary study, Czerwinski et al. [19] found that people did not resume tasks immediately after 40% of the interruptions. Iqbal et al. [38] found that after an email and instant message interruption users take about 10 to 15 minutes to get back to their primary tasks. In a study with 50 participants, Bailey et al. [2] found that task time increased by 3 to 26% when the user was interrupted in the middle of a primary task and the work-related errors doubled. Apart from the impact on work and productivity, interruptions in the middle of a user's primary task also increase annoyance by 31% to 106% and the user can experience twice the increase in anxiety [2]. These works demonstrate that untimely interruptions like generic break reminder software is a deterrent to the user's productivity and mental health. In case of less urgent but important and frequent tasks like rest breaks, using intrusive notifications means a consistent disruption of the workflow and increase in stress and anxiety. This creates the need for non-intrusive break reminders that provide awareness about the need for a break but do not adversely affect the productivity and affective state of the user.

2.2.2 Calm Technologies as Interruptions

Bailey et al. [2] found out that when users were interrupted for peripheral task in between two primary tasks, it did not have an adverse effect on their task time, error rate, and affective state when compared to interruption in between a particular primary task. From the result of this study, they suggest the need for an 'attention-aware' system to interrupt the user for peripheral tasks when the user loses attention. Another way to look at it could be that the system exists in the periphery of the user's environment and switches to the center of attention for the transient moment when the user loses attention from the primary task.

Calm technologies have the ability to switch from the user's periphery to the center of attention [79]. They are calming because being in the 'periphery' in this context means that the user is attuned to its existence [84]. By being in the periphery, they offer the advantage of communicating information at the disposal of the user, thus, preventing overburdening of information when the user is occupied. This is often done by integrating the digital information (the information to be communicated) with the environment (something the user is attuned to) of the user [35]. This integration of the physical and the digital also means that there are two facets that designers should take care of: the functionality of the digital information and the aesthetics of the integration with the physical environment [35].

Prior work demonstrates the integration of user's physical and digital world using auditory and visual cues [16,43,66]. For example, embedding auditory cues in ambient soundscapes [16], using lights to embed an ambient display in the wall that communicates information by lighting in different patterns [66], shape-changing circuits that communicate information through subtle change in physical form [31,43] to provide peripheral feedback to the user. These capabilities offer a great advantage in contexts like frequent break reminders, where the information to be communicated is important but not urgent, it can be communicated over a longer period, and where more intrusive and immediate methods could cause potential annoyance to the user [2].

2.3 Tangible User Interfaces and Shape-Changing Devices

Tangible user interfaces (TUI) are physical objects that embody digital information [40]. They can exist in the user's peripheral vision, by integrating with the physical objects present in the environment. In Objects for Change [89], Zuckerman et al. brings together the theories of behavior change and TUI. They argue that the persistency and visibility, locality, tangible representation, and affordances of TUI are effective features required for changing behavior. Renfree et al. [68] present a case for leveraging the ambient nature of TUI by placing them in office environment to reduce sedentariness. They use light to make the user aware of their level of sedentariness. In addition to light, other medium of communicating ambient media can be sound, airflow, and movement [39].

Shape-changing devices are advanced TUI, capable of communicating ambient information through slow movement in the periphery of the user [43]. Rasmussen et al.

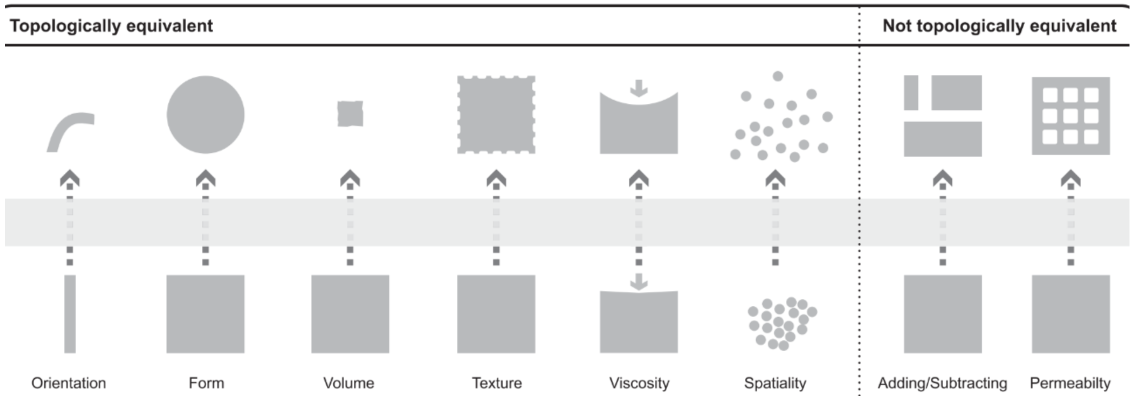


Figure 2: Physical transformation of shape-changing devices [67]

[67] classify shape changing devices as tangible user interfaces that can self-actuate to change their physical properties as an input or an output. This physical transformation can include change in orientation, form, volume, texture, viscosity, or spatiality (See Figure 2). These transformations in the form of input or/and output are used to for functional and hedonic purposes in the literature. For the functional purpose, shape-changing devices communicate information in a more expressive and effective manner and use dynamic affordances to communicate the possibilities of actions [67]. The expressive parameters depend on the perception of the affect of physical transformation. Apart from being effective for information communication, keeping the physical transformation slow and quiet can keep them in the periphery, as in the case of calm technology [43]. These qualities of shape-changing devices to communicate information in an expressive yet quiet manner demonstrates the potential for them to be effective break reminders at work [69].

There is an extensive body of work about fabrication and possible applications [57,58,59,61,88] of shape-changing interfaces. Shape-changing interfaces use self/user actuation to change physical shape/materiality as an input or output [1,67]. This change in physical form in the fabrication process is facilitated by different methods including coefficient of expansion, pneumatic pressure, layer jamming, and motors. These changes when slow and quiet, can exist in the peripheral vision of the user [43]. These hedonic and functional applications demonstrated in prior work include communicating emotion [69], communicating information [43,67], dynamic affordances that fit the context [36], and volume change for portability [44].

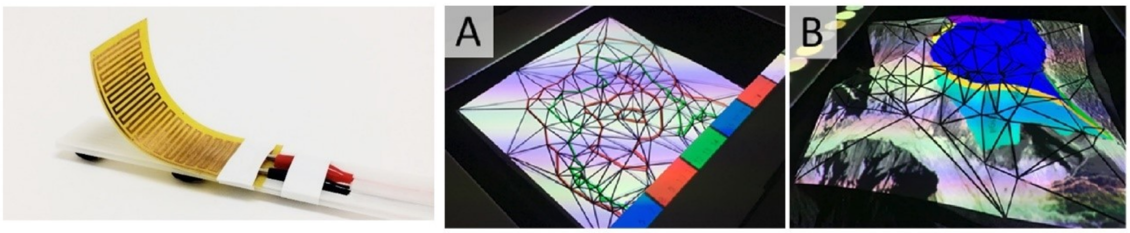


Figure 3: Shape-change as ambient notifications as calm interruptions during work [38] and for information visualization [21]

Only few works in the literature applies shape change to the objects of the workplace. Seoktae et al. [44] present a practical application as an inflatable mouse that facilitates portability through volume change. A few other approaches include the use of physical and vibrotactile feedback from the chair to facilitate posture change while sitting [34], shape change as an ambient notification system during work activities [43], in-pocket notifications [23], and shape change for information visualization for diverse datasets such as numeric and text data, GIS information, and, x and y coordinates [26].

In BreakAway [41], a shape-changing sculpture that suggests breaks through multiple degrees of slouching, Jafarniami. et al. 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. Jones et al. [43] evaluated the effectiveness of shape-changing circuits to provide passive awareness without disrupting the productivity of the user. They found that the near periphery of the user is ideal for ambient notification to work.

These works demonstrate the potential of shape-changing devices 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 the break reminders. Hence, for long-term adherence and adaptability of such devices, it is important to understand their terms of acceptance in the wild.

2.4 Participatory Design

Participatory design began as a Scandinavian movement to democratize work place in the 1970s [76]. It attempts to understand the tacit knowledge of human activity. It draws on various research methods (such as interview analysis, ethnographic observation) to enable researchers and users to cooperatively create design artefacts, workflow, and work environments.

User-centered design is the other method of involving the users in the development of a product/process [72]. Unlike participatory design, where users are co-designers who are 'experts of their own experiences,' user-centered design revolves around the role of users as passive contributors, who give interviews and perform user testing under the observation of a trained researcher. Collectively called as human-centered design research, Sanders [72] illustrates this landscape based on current practices in Figure 4. We intend to include users as partners in our study. Hence, we position our work in the area of participatory design research.

We review work in participatory design to understand the process of involving the user early in the process of designing an effective shape-changing break reminder. We start with reviewing the history and motivation followed by prevalent participatory design

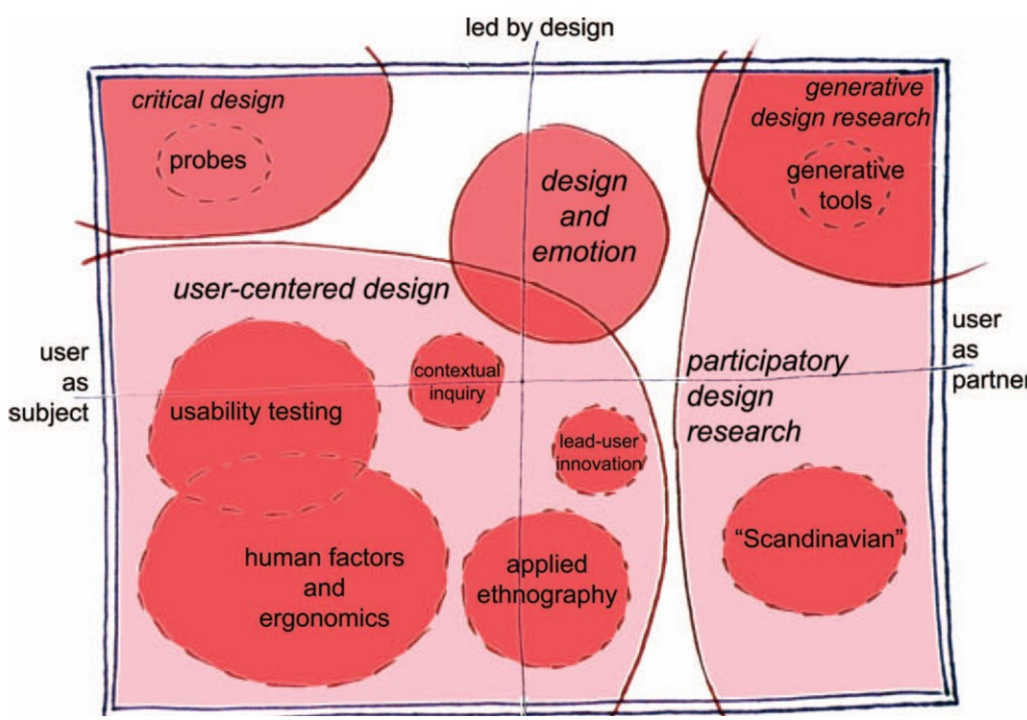


Figure 4: The landscape of human-centered design [72]

methods used in the field, in the end we discuss the practice of participatory design in HCI, Health, and accessibility.

2.4.1 History and Motivation of Participatory Design

Participatory design has its roots in the post-war ’60s and the ’70s in Scandinavia [32]. It was developed as a measure to democratize industries by including them in the decision-making process. This method emerged as a method to improve the work process and environment by giving the workers the opportunity to participate in the decision-making that directly influenced their work. The early motivation of participatory design was to 1) gain in-depth knowledge of the system, about how it is built and how it works; 2) build realistic expectations in people and reducing their resistance to change by including them in the process; and 3) increase the workplace democracy by involving all stakeholders in the process.

Coming to recent years, the participatory design approach has moved from just being a lever to workplace democracy to a more public sphere [9]. More commonly called as Co-design now, it is being used to address the concern of representation of the users to design better systems, especially for target groups with specific needs [7,73,78,81,87]. Researchers have used this method to include users in the design process in envisioning future software design [78,81,87], healthcare systems [73], and designing for a population with specific needs (for example: older adults, people with disability) [7]. This has led to the re-orientation of the motivation to 1) democratizing the design process; 2) informing the future of a design system; and 3) including users in the construction of their own futures [60].

2.4.2 Participatory Design Methodologies

In participatory design, the user is a fully empowered participant in the design process, envisioning, forming, and shaping the design of future artefacts [76]. To elicit tacit knowledge of the user, the design of the design process is as important as the artefact itself.

In the context of the workplace, participatory ergonomics (PE) involves actively including workers in the process of designing, developing, and implementing workplace changes in order to improve the productivity and reduce health risks [15]. The artefact being designed could be a product, process, or the environment, depending on the context and need of the problem being addressed. While earlier works in PE address improving ongoing processes and existing environments, later works extend PE to establishing new products and processes and seem to be more widespread today [13]. Design of products and processes that do not exist raises the issue of involving workers to design and conceptualize something that does not exist. This is where boundary objects are brought in, as they are means of communication to enable the participatory design process. Broberg et al. [13] categorize boundary objects in to five groups: repositories; objects, models, and maps; discourses; and processes. Based on two cases studies they conceptualize boundary objects as objects-in-the making with built-in affordances that are flexible and malleable.

Another example of using artefacts are mockups like UTOPIA [25]. It demonstrates the use of low fidelity design artefacts to create an organization kit game that is the center of design dialogue between the researcher and the user. Researchers designed this game for typographers, journalists, and other stakeholders involved in newspaper production to define production flow, identify materials and artefacts used in the process. These designed artefacts are types of probes that help the designers to collect insights from the user. This demonstrates the use of low fidelity design artefacts to elicit tacit knowledge of the user.

Sanders [71] presents a framework to organize tools are techniques in a codesign session based on the form (making, telling, enacting), purpose (probing, priming, understanding or generating) and context (individual, group, face-to-face, online). According to the framework, to make tangible things, 2d triggers using verbal and visual cues can work for probing, priming, understanding, and generating. Using materials like foam or Legos are particularly useful for the process of understanding and generating.

This suggests that probing and prototyping using verbal cues, imagery, and mockups could be appropriate techniques in the participatory design method in the context of identifying challenges faced by people with RSI at work, and capturing their desires from a tangible, shape-changing break reminder system.

2.4.3 Participatory Design in HCI

While the founding proposition of participatory design was to democratize the workplace. HCI researchers often use it to bring the voices of the users that have traditionally been excluded [11,29,45,49,80,83]. These typically include seniors and children, moving the context of participatory design beyond the workplace, to rehabilitation [45], museums [75], and resident care [11]. Vines et al. [83] conducted multiple workshops with 16 octogenarians to design a digital cheque clearing system for them. These workshops were organized at different stages of development of the product. The participants were first introduced to the use of technology (Anoto pen: a camera embedded pen that can digitize writing on a paper) in different scenarios to investigate their skepticism or receptiveness to this technology. They used these insights to build a digital cheque clearing kit and used it in multiple workshops to understand if the system could work for them. In participatory design for elderly people, much work has been also done in the context of health and accessibility. We discuss this in detail in section 2.4.4

As an early example of participatory design in software development, Bødker et al. [12] proposes a cooperative prototyping approach. Using this method, they actively involve users in the design and evaluation of early developed prototypes. In their analysis of the design of computer support for casework in a technical department of a local government, they present different situations of cooperative prototyping and learning opportunities when the focus shifts from the researcher’s expectations. One such situation is generating and exploring ideas through articulation. Here they use the prototype as a ‘thing’ to generate discussions about the workflow. In such situations the opportunities for new insights open if the researcher can improvise the prototype in real time in case the user takes a segue while articulating.

Another common application of participatory design research in HCI is in the form of gesture elicitation studies [55]. It has gained popularity in designing input gestures for post window, icons, menu, pointer (WIMP) interfaces, like surface computing [87], in air gestures for TV control [81], augmented reality [65], and deformable user interfaces [78]. These studies have their roots in participatory design as researchers use gesture elicitation to formulate more discoverable and memorable gestures [87]. These studies question the existing pre-defined gestures and address the issue related to gestures being defined by systems engineers that perhaps take into consideration the technical limitations of the system over that user behavior.

While gesture elicitation studies are useful to understand and identify interaction techniques that work well for the end user, Morris et al. [55] point out that one potential drawback is that these gestures can be heavily influenced by the user's prior experience of WIMP interfaces. They term this bias as ‘legacy bias’ and propose three techniques *Production*, *Priming*, and *Partners* that can address this bias if incorporated in the participatory design process. They describe the three methods as; *Production*: asking users to come up with multiple gestures for one application; *Priming*: introducing users to new form factors (such as videos); *Partners*: Asking users to perform gesture elicitation in groups rather than alone. Both the works by Bødker et al. [12] and Morris et al. [55] reinforce the pivotal role of probing through design artefacts such as prototypes or videos to scaffold the creativity of the user.

As the context and intent of participatory design research changes in HCI, there are some concerns that the researcher should consider before the practice of this method [82]. The political and moral underpinning of participatory design research is to give the users a say in the technology they will end up using. While using these research methods, the researcher should take a step back and reflect on who is the beneficiary as a result of this participation. Other concerns that the researcher should account for is that who shares the agency of the design and the motivation behind including the users in the process, i.e. commercial or the welfare of the user.

2.4.4 Participatory Design for Health & Accessibility

In the context of health and accessibility, it is critical to involve users early in the process of product research and development, as the users' needs are specific and different from the designer [85]. Users in this context have an acute awareness of their contexts and the problems that they face [42]. Participatory design in health has focused on the people with health problems [49,86] as well as healthcare professionals [10].

In the context of healthcare and accessibility, the researchers are typically dealing with vulnerable populations, and in such a context, it is important to establish a relationship of trust with the participants to enable them to contribute effectively [49].

Uzor et al. [80] conducted a participatory design sessions with older adults to design tools for fall rehabilitation. They found that the game design solely by seniors was popular amongst other participants. Their study demonstrates that seniors can be effective contributors in the design of technology that would work for them.

Balaam et al. [45] conducted multiple participatory design sessions for upper limb mobility in a home environment amongst people who have suffered from stroke. They found that people have diverse motivations and strategies for recovery. They learned that researchers should help participants articulate what motivates them, provide support for these motivations over time, and balance duty, work and fun in the context of recovery. These works demonstrate the benefit of empowering people to design and contribute in the development of the technological artefacts that they desire to use in the future.

2.4.5 Psychological Theories of Behavior Change and Motivation

The core construct of the Transtheoretical model of behavior change is the 6 stages through which an individual progresses to establish new behavior [62]. The core constructs of this model are “1) Precontemplation—individuals have no recognition of the need to change and, consequently, no intention to take action; 2) Contemplation—intention to take action within foreseeable future (next six months); 3) Preparation—intention to take action within immediate future (next 30 days and having taken initial preparatory steps); 4) Action—practicing new behavior for 3 to 6 months; 5) Maintenance—continuing commitment to sustaining behavior; 6) Termination—overt behavior will never return”.

Sunny et al. [18] describes that the stage of the user might direct the design approach to support the progress to the next stage. In stage 1, where the individual doesn’t even recognize the problem may be made aware through data. In stages 2 and 3, the user intends to take action in the foreseeable or near future, behavior change can be supported through overcoming barriers and giving rewards. For individuals in stage 3, starting to practice a new behavior, immediate feedback can be given for inconsistencies. For stage 5, having practiced the behavior for a while, progress can be highlighted showing how long the individual has come and how far ahead can he or she go.

According to Bandura [5], the conceptual model of behavior change rests of efficacy expectations and the outcome expectation. The efficacy expectation determines if an individual think that he or she can perform the task to overcome the challenges and the outcome expectation is whether the task will overcome the challenges. Thus, efficacy expectation becomes critical as it determines whether an individual will expend the effort to overcome challenge and how long will they persist in the face of adversity.

The goal setting theory by Locke et al. [50] is based on the self-efficacy theory [5]. It influences work motivation in individuals by suggesting that individual's performance will be maximized when "(1) they set specific, difficult goals that have high valence and (2) they understand what behaviors will lead to the goals and feel competent to do those behaviors." Unlike the goal setting theory, the self-determination theory makes a distinction between different kinds of motivation [22]. They define motivation as involving intentionality to act. The intentionality can be autonomous (i.e. intrinsic motivation and well-internalized extrinsic motivation) or controlled (i.e. feeling coerced or seduced by external contingencies).

2.5 Summary

In this chapter we learned that taking microbreaks is an effective method of reducing the symptoms of RSI. These can be difficult to take in the middle of work, especially when the user is motivated to continue working. Existing technological interventions like desktop and phone notifications are can be inadequate because they are untimely and adversely impact the affective state and productivity of the users. While these immediate notifications can be customized to accommodate for more appropriate timings, they are incapable of being aware of user's natural work-pause pattern and accommodate the changing context at work. (For example, be less intrusive on a busy day or when someone else is present). In such cases, non-intrusive reminders demonstrate potential as they give the user the ability to choose when to pay attention to the reminder. While this could mean less breaks initially, it could help users to act based on their perceived self-efficacy and slowly move through the different stages of the transtheoretical model of behavior change.

While prior work has investigated the effect of break reminders on break taking and user’s perception of such interventions, not much is known from the perspective of people who have the experience of incorporating rest and movement during work. People with RSI could bring new insights to the body of work of break-reminders as it is more critical, and they are often prescribed to take breaks. Participatory research methods can be used to include these people as design partners and equal contributors in adding new knowledge to the body of work of break taking during work and shaping the technology that they will use in the future.

Chapter 3: Understanding the Design Space

3.1 Introduction

In this chapter, we conduct an ideation session with 8 HCI professionals. To facilitate free-flowing ideas that are still rooted in research, we create a 2-dimensional ideation space in the form of a graph. We determined these two scales using a three-step process (Figure 5): 1) We identify two major design challenges for making an effective shape-changing break reminders from the literature; 2) We translate these two design challenges into design objectives; and 3) We expand these two design objectives to create the two scales; the physical integration and the activity intervention scale.

Through ideas generated in the graph and its analysis, we attempt to understand the design space in cooperation with HCI professionals, as they are already familiar with the domain. We aim to apply this new knowledge in further sessions with end-users, who would typically find the domain of TUI and shape-changing devices novel.

3.2 Defining the Design Challenges, the Design Objectives, and the Scales

In placing a shape-changing break reminder in the users workplace, we identify two major challenges from the prior work; the integration of the break reminder with the work environment of the user and causing minimum disruption to workflow while suggesting a break.

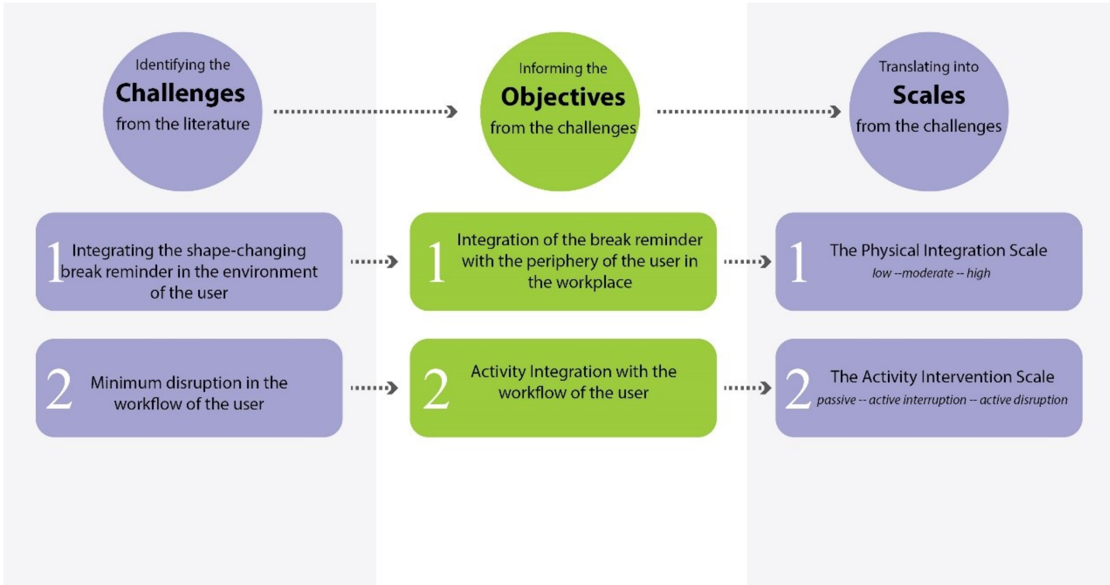


Figure 5: The three-step process of identifying challenges, using them to inform the objectives, and translating objective into the two scales, to use within the design session.

3.2.1 Challenge 1 — Integrating the shape-changing break reminder in the environment of the user

In chapter 2, we presented prior work that demonstrates the inadequacy of generic notifications in the context of break reminders. They adversely influence the productivity and affective state of the user. In this scenario, calm technology shows potential as they have the capability to exist in the periphery of the user, presenting the digital information at user's own accord, without overburdening them with information. For the digital information being communicated to be calm the physical artefact that embodies it should blend in the user's environment. Whether the physical objects blend in by attaching themselves to the computer devices that are ubiquitous in the workplace or by just moving away from the user is difficult to evaluate without experimentation. However, the challenge here remains that the physical artefact, i.e. the shape-changing break reminder, should integrate with the environment of the user. This brings us to our first design objective.

Objective 1: Integration of the break reminder with the periphery of the user in the workplace

It is crucial for the shape-changing break reminder to be a part of user's peripheral environment for it to be ambient. By being in the periphery, the artefact makes the user attuned of its existence. This implies that there has to be a physical integration of artefacts with the workspace of the user. However, it is difficult to theoretically conclude what that peripheral integration would mean. We expand the design objective to a scale of physical integration to speculate with HCI professionals, and later with end users, what physical integration with the workspace means to them.

Scale 1: The Physical Integration Scale

This scale invites the designer to think about the integration of the device with the ecosystem of the user. We particularly see this as a scale based on the level of integration of the rehabilitation device with the workplace. We see three points on the scale as: low; moderate; and high level of integration.

- A low level of integration means that the object looks completely out of place in the workplace. For example, a toothbrush on a dinner table at a restaurant. It does not belong to the dinner table and it would make one wonder why it is there.
- A moderate level of integration would mean that the object lies somewhere in between high and low level of integration. For example, a spoon on a desk in an office. It does not belong in a workplace, but it is not hard to imagine a scenario that would have brought it on the desk.

- A high level of integration means the object is an obvious part of the workplace. For example, a couch in the living room, pots in the kitchen or hangers in the closet.

3.2.2 Challenge 2: Minimum Disruption in the Workflow of the User

Prior work (Section 2.2.1) demonstrates the adverse effect of interruptions (desktop and phone notifications) on the affective state of the users and their productivity. This means that the break reminder should be least disruption to the workflow of the user.

Objective 2: Activity Integration with the Workflow of the User

While attempting to make these devices blend in the user's environment and be less disruptive to workflow, we run the risk of making the device invisible, or at least hardly noticeable. To speculate about the different levels of visibility of the digital information presented to the user, we expand the design objective activity integration with the workflow to the activity intervention scale. HCI professional in the ideation session, and later use this to speculate the acceptable level of intervention acceptable to the user during work.

Scale 2: The Activity Intervention Scale

This scale invites the designers to think about what type of intervention the device has. We particularly see the type of intervention as a scale based on the impact of reconfiguration on the work flow. We see three points on the scale as: Passive Intervention; Active Interruption; and Active Disruption.

- Passive intervention. The object of intervention may divide the user's attention but does not actively interfere with the user's workflow (e.g. partially cover up some of their display screen while they are completing a task).

- Active interruption. The object of intervention partially interferes with workflow but does not prevent the user from continuing the task. For example, a pop-up notification covering a small part of the screen suggesting the user to stop using social media after a pre-decided threshold.
- Active disruption. The object of intervention prevents the user from doing the task before the intervention. For example, the web browser blocking the website for a specific amount of time preventing the user from using the social media at that moment after a pre-decided threshold of usage.

We wanted to design an object that integrates with the workspace and the workflow of the user. We used this to create a graph with the physical integration of the object with the workspace (low-moderate-high) on the Y axis and activity intervention (passive-interruption-disruption) on the X-axis. We created the graph to understand the type of solutions possible in the different locations of this graph. This practice is commonly adopted in design research for product positioning, understanding gaps, and intervention areas [47].

3.3 Participants

We conducted the ideation session with 8 HCI professionals in academia. We chose HCI professionals because they may be more effective to generate many ideas in a novel domain like shape-changing interfaces than people with RSI or physiotherapists. This is important to frame the design space that would later facilitate discussions with participant demographics unfamiliar with the domain of shape-changing interfaces. Our participants included 2 undergraduate students, 2 master students, 2 PhD students, 1 postdoctoral fellow and 1 faculty member.

3.4 Procedure

The session lasted for about 2 hours. We presented the concept of shape-changing interfaces, RSI, and the ideal work habits. We put the healthy work habits as prompts on the ideation wall because it was an unfamiliar subject for the HCI experts.

We started the session with asking the participants to write down different environments in typical day on a card and place them on the wall. Afterwards, we asked them to name various objects, and put them up as a different cluster. After we had about 4 to 5 objects per participant, we introduced them to 'Activity Intervention Scale' and the 'Physical Integration Scale' as the X and Y axis on a graph. The participants picked an object of their choice and added an interaction that would explain how the object would support RSI. Once they had the 'object' and 'interaction' card, they picked up an 'ecosystem' card that made sense for the object. They placed the stack of an object, interaction, and ecosystem cards on the graph at a location that seemed appropriate to them. We used this exercise as a warm up to familiarize participants with the scales, graph and generally start thinking about objects and ecosystems. This was important to get them thinking about objects outside the workplace first. We also did this to allow inadvertent design discoveries that could have been obscured by our design objectives.

In the next step, we restricted the ecosystem to the workplace. Participants brainstormed objects of and outside the workplace and created a new cluster on the wall. We asked the participants to pick objects in or outside the workplace environment, add an interaction that would explain how the object supports RSI, and place them on the graph. We did not restrict the ideas to shape change and we asked them to not think about acceptance of the idea or annoyance but to put as many ideas that come to their mind. We did this to have a

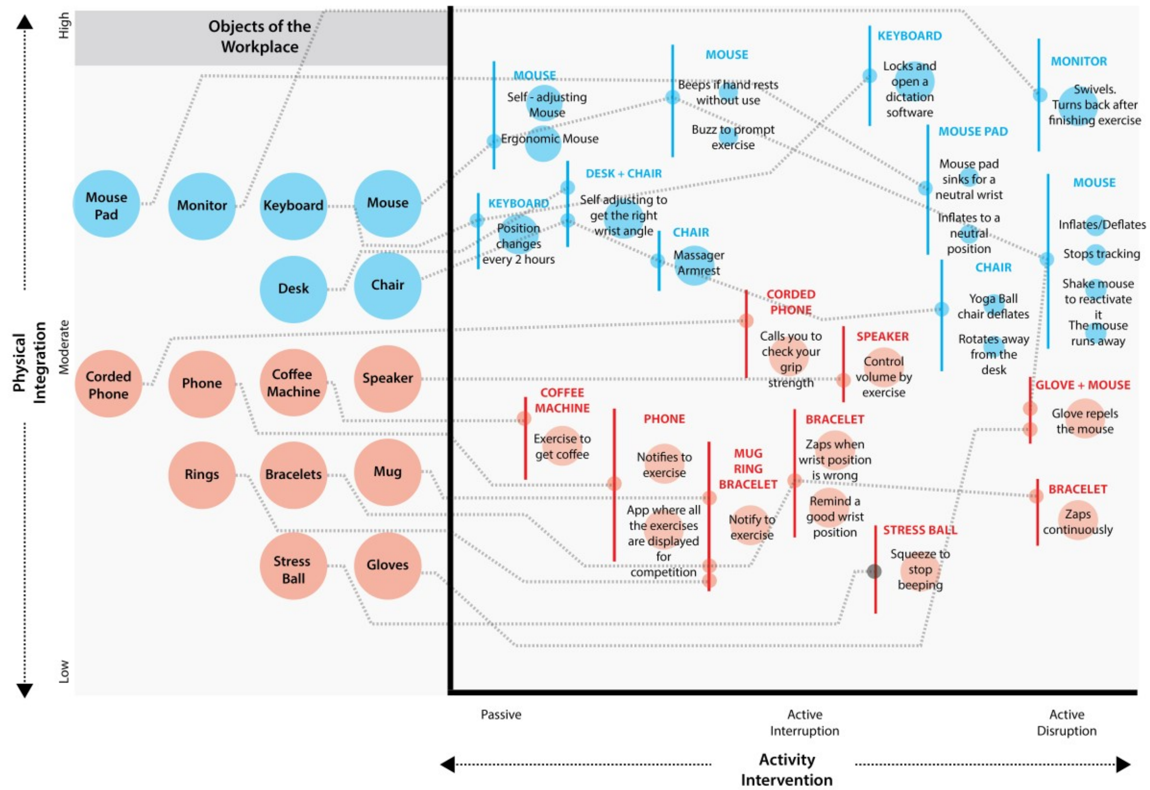


Figure 6: Ideas generated by the participants on the graph with activity intervention on the X axis and physical integration on the Y axis.

varied combination and a lot of ideas that would enable us to find patterns in collocated ideas and frame the design space. After approximately 35 ideas on the graph (Figure 6), we ended the session with an open discussion of 20 minutes.

3.5 Results

After the session, we analyzed the designs on the graph to identify patterns in different areas of the graph. Based on the analysis, 6 categories emerged (Figure 7). This helped us to segment the graph into 6 distinct boxes and identify which boxes have potential to become break reminder system based on the type of object and their interaction. The six categories were

C1 - external objects to support better posture (low integration + passive intervention);

C2 - external objects to probe exercise/break (low integration + active interruption);

C3 - external objects to force exercise/break (low integration + active disruption);

C4 - objects of the workplace to support better posture (high integration + passive intervention);

C5 - objects of the workplace to exercise/break (high integration + active interruption);

C6 - objects of the workplace to force exercise/break (high integration + active disruption).

C1) Low to Moderate Integration + Passive Intervention

This category includes objects external to the workplace environment that support correct posture, these objects have the intent of not disrupting the workflow of the user.

C2) Low to Moderate Integration + Active Interruption

The participants mapped most objects with moderate level of integration, these objects included mugs, ring, bracelet, and the phone. Most of the objects performed interactions like zapping, beeping, lighting up to suggest the user to take a break or exercise. The general theme in this space was objects external to the workplace environment that nudge or probe the user to rest or exercise.

C3) Low to Moderate Integration + Active Disruption

The objects mapped in this category were similar in 'Low to Moderate Integration + Active Interruption.' The interaction of these objects changed to continuous beeping and zapping that prevent the user from continuing work and act on what the device wants.

The general theme of this space was objects external to the workplace that prevent the user from continuing work.

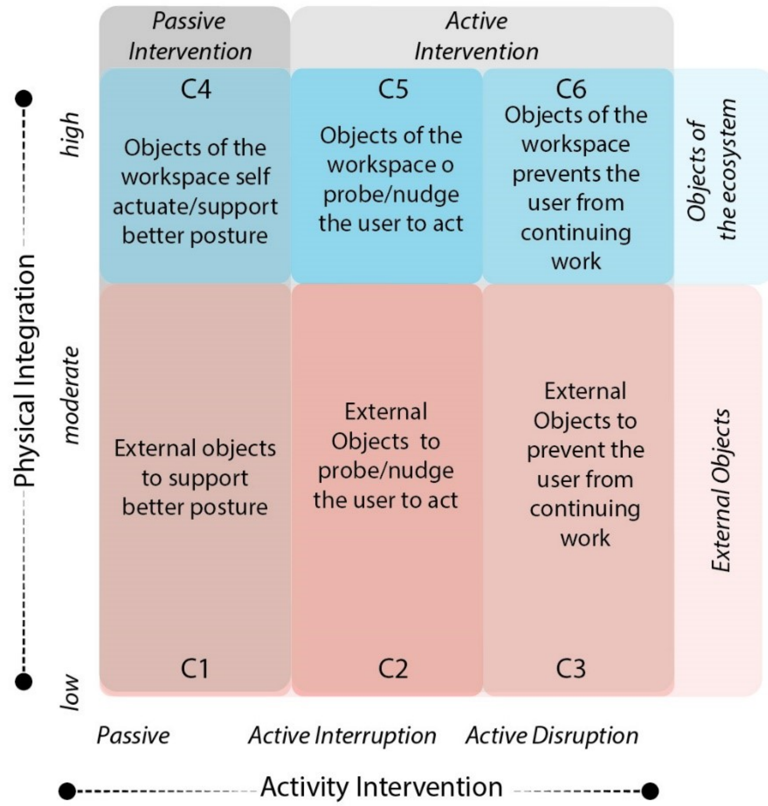


Figure 7: Results of the ideation session as 6 categories on the graph

C4) High Integration + Passive Intervention

The participant mapped objects like the mouse, keyboard, desk, and chair in this space. The common factor between these objects was that the user was constantly in physical touch with these objects. This enabled the objects to support correct posture by being in the background. None of the ideas in this category targeted towards exercise. Participants presented objects like the keyboard changing inclination angle at regular intervals to vary the posture, and an ergonomic mouse that supported correct posture. The general theme of this space was the object of the workplace either statically or through self-actuation support correct posture.

C5) High Integration + Active Interruption

The participants mapped objects like the mouse and keyboard. They used interactions like beeping and vibrating to suggest posture change or exercise. The general theme of this space was objects of the workplace that nudge/probe the user to take a break or exercise.

C6) High Integration + Active Disruption

The category had the greatest number of ideas. Participants mapped objects that were critical to the workflow like the mouse, keyboard, monitor, desk, and chair. They primarily manipulated the physical orientation or the location of these objects to create disruption. Some of the ideas were the monitor swivel away from the user and returns after exercise, the chair is a yoga ball that deflates when there is a lot of repetitive motion of the wrist. The general theme of this space was objects of the workplace that reconfigure to prevent the user from continuing work to suggest rest or exercise software for typing, the monitor swiveling away and returning only after exercise.

3.6 Discussion

The idea generated in the session helped us to understand the design objectives. We did not restrict the ideation session to the context of break reminders in order to frame a larger space created by the two scales (physical integration and activity intervention). We looped back to the initial challenges, objective, and scales and reflect on them.

To address the objective of integrating the break reminders with the periphery of the user means to balance between being ambient and visible. This may mean different to different users based on factors the perceived importance of taking breaks. Based on this perception, the user may prefer a certain level of integration at the physical integration scale.

Similarly, in the case of activity integration with the workflow of the user, this design objective enables types of interaction to transcend from one end of the activity intervention scale to the other. For example, a mouse could support correct posture by the virtue of its form (passive integration). After a certain threshold of use, it may vibrate to suggest the user to take their hands off and take a break (active interruption). If the user chooses to ignore the interruptions, the mouse may deflate to prevent the user from working (active disruption).

It is also critical to consider the user's entire workday, not only the active work tasks. Specifically, we want to point to transitions in work activity. Instead of creating work breaks through interruption or disruption, the device can support rehabilititive practices during breaks. An interesting idea that came in the workshop was the need to perform exercise to get coffee. Such strategies are common in combating sedentary lifestyle in everyday life, like biking to work, taking the staircase instead of the elevator. People use transition to incorporate healthy habits and technology can be designed to support it. Similarly, transition moments like smoke, water or coffee breaks can be used, and breaks can be interrupted or disrupted instead of work.

We now reflect and identify relevant categories from the results of the ideation session to position shape-changing break reminders in the design space.

Category C1 and C4, both passive interventions, included objects that self-actuated to support better posture. While, this category has potential to track, and correct the posture of the user, it does not demonstrate potential for a break reminder as there needs to be an intervention (intrusive or non-intrusive) to remind the user to take a break.

Category C2 and C5, both contain active interruption, demonstrate potential for non-intrusive break reminders. These can include embedding interruption in the objects of the workplace, or in personal objects that are present in the workplace of the user.

While Category C3 and C6, both including active disruption are more suitable for intrusive break reminders, they do demonstrate potential for investigation. As it is worth investigating how people with RSI feel about disruption for their wellbeing.

Chapter 4: Interactive Session with people with Repetitive Strain Injury

4.1 Introduction

In the previous chapter, we conducted an Ideation session with people with an HCI background to define the design space of shape-changing break reminder for people with repetitive strain injury. Here we used the insights from this study to conduct interactive sessions with people with RSI and understand their challenges, preferences, and unspoken desires from a break reminder system. We conducted the session in three parts:

1. The **Interview**: where participants describe challenges and pain points of having RSI at work. We conduct the interview to answer the following research question:

   Q1: What strategies do people with RSI use to incorporate breaks and other healthy work habits?

2. The **Design Critique**: where participants give their initial impressions of design probes positioned strategically in the design space. We conduct the design critique to answer the following research question:

   Q2: What are their impressions of external objects or objects of the workplace suggesting or forcing as interruptions and disruptions to suggest breaks?

3. The **Participatory Design Session**: where they express their unspoken needs and desires by designing something for themselves. We conduct the participatory design session to answer the following research question:

   Q3: What do they desire from a tangible object that can support them to take breaks and exercise?

4.2 Procedure

An interactive session lasted for an hour on a single day. The session was divided into three consecutive phases: the interview, the design critique, and the participatory design session. To facilitate discussion about the participant's work environment through the entire session, we conducted the session in their work place. When that was not feasible, we asked them to get a few pictures of their workplace for the session.

4.2.1 Phase 1: Interview: Coping strategies and challenges faced in incorporating healthy behavior.

We seeked to understand the context of working with RSI, challenges faced by these people and the strategies employed to cope with it. In addition to these questions, we ask general questions about their work habits and their workplace primes them to elicit responses from their personal experiences. We supplement the interviews with an observation of the level of privacy, space availability for personal objects, and the presence of objects of decoration or personal preference in the workplace. We do this to ask specific questions about their personal preferences and feasibility of having a shape-changing device as a break reminder.

4.2.2 Phase 2: The Design Critique: Capture early impressions of design probes

To understand the perception of shape-changing device as a break reminder system, we use design probes to create these discussions. Probes are a common technique is design research to map context, provoke participants to rethink their environment, and respond in a way that creates a dialogue between the participants and the researcher [4]. In the context of our study, these probes give a tangible form to an otherwise abstract idea of shape-changing devices for the participants. They are not a suggestion of what a device should be, but a model for creating discussion and capturing thoughts and preferences of the participants. They equip our participants to think about the possibilities of what the shape-changing device could look like and how it could interact with them. This can enable them to critique the probes and in the next phase, envision a solution that meets their personal needs. As critiquing and envisioning pivots around our design probes we followed a process common in design research [47] to determine what these probes could be.

The intention behind structuring the session from interview to design critique of shape-changing devices to the participatory design workshop was to start from a descriptive activity and gradually move to an imaginative mindset, essential for designing unfamiliar objects such as shape-changing devices.

4.2.2.1 Positioning the Design Probes in the Design Space

We identified relevant categories for break reminders and chose design probes that belong to each category. We did this to cover the design space, have well-positioned design probes (Figure 8) that represent a larger space.

Out of the six categories (Figure 8) identified from the ideation session described in chapter 3, we select four categories (C2, C3, C5, & C6) that could include shape-changing devices as a break reminder. We excluded the categories with passive intervention + low to moderate (C1) and passive intervention + high integration (C4) included objects as they were suited to support better posture. We use two design probes each cover the two different levels of activity intervention (Figure 8). So, in total we have four probes, one for each of four categories (C2, C3, C5, & C6).

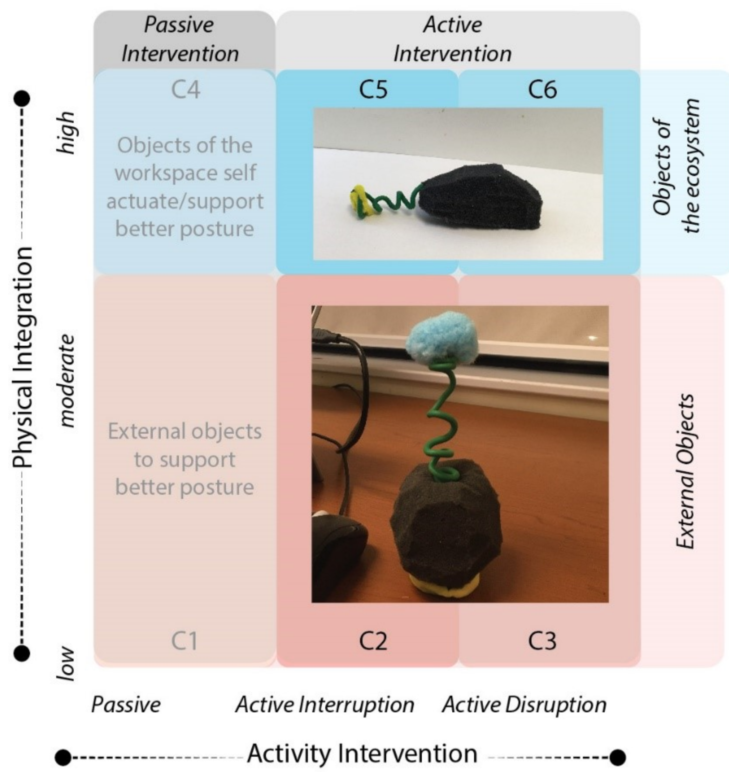


Figure 8: Positioning the Design Probes in the Design Space

4.2.2.2 Design Probes

After identifying the position of the design provocation in the design space, we identified design features that would determine the aesthetic of the product. The design probes were intentionally crude aesthetically and low-fidelity. In UX Research methods, low-fidelity prototypes put less pressure on the participants [64]. This happens because they do not assume that it took a large effort from the researcher to create these, and they are likely to be more critical. In the case of our design probes, the crude aesthetic quality and lack of embedded technology makes it easier for the participants to elicit critical responses and generating rich data. In addition to the low fidelity of the design probes, we use the materials from the prototyping kit to make design probes and the process of participatory design more approachable. This gives the participants the confidence that they could build something of at least similar fidelity to the design probes. We selected the following design provocations to cover the intended design space.

4.2.2.2.1 Probe 1: External Object

A flower (Figure 9), if present in the workplace, is an object of personal choice, with perhaps an aesthetical function. Hence, it could be an external object to the workplace. We made the stem of the flower with a malleable wire and the vase with foam. The choice of a flower also gave the ability to capture opinions of an animate object in this category (C2 & C3). We decided the level of fidelity based on the time allotted (15 minutes) to prototyping in the interactive session.

Story of the probe: The flower formed the center of the following fictional story that we told our participants to introduce the probes: "*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 wither, suggesting users to get up and take a break. You can restore the life of the flower by taking a break.*"

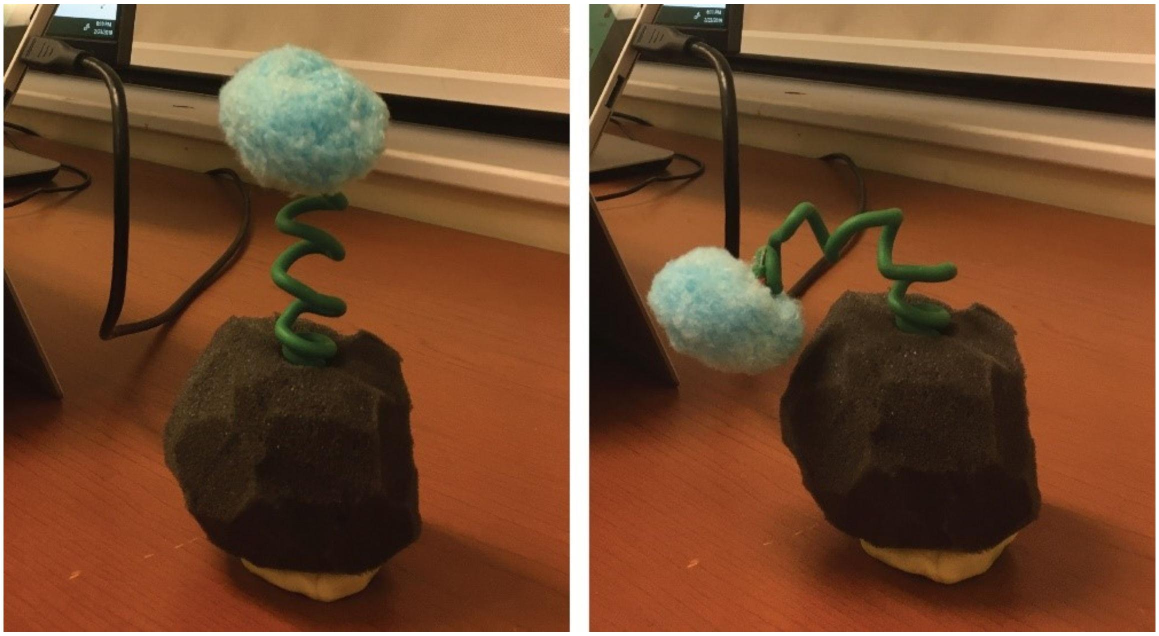


Figure 9: The flower standing tall as a default and withering to suggest a break.

On the activity intervention scale, we used the same external object to demonstrate two levels of intervention: Interruption and Disruption.

External Object & Interruption

This design probe is positioned in the category C2 in the design space as described in Figure 8. In order to ensure an interruption, the withering of the flower is the only change that happens in the work environment of the user. This means that the feedback is only visual and happens in the peripheral vision of the user.

External Object & Disruption

This design probe is positioned in the category C3 in the design space as described in Figure 8. To ensure disruption, the withering of the flower prevents the user from continuing work by degrading the usability of the workplace devices (for example: the mouse or the keyboard becomes harder to use). This may occur after the user ignores a few instances of interruptions.

4.2.2.2.2 Probe 2: Object of the Workplace

The object of the workplace as a design probe introduces the possibility of having a shape-changing attachment to a computer device as a break reminder. We chose the mouse because of its portability, but also explained further that it could be attached to any computer devices (for example the keyboard or the monitor) in the participant's work space. The mouse had a malleable wire in form of a spring, like the flower, and the spring has a circular button attached at the end (Figure 10). We made the mouse with the same foam used for the vase of the flower. Same materiality establishes a consistent aesthetic quality and the level of fidelity for the two probes.

Story of the probe: Similar to design probe 1, we told the following fictional story to our participants to introduce design probe 2: "*The mouse has a small button attached to the spring at the front of the object. The springs extend itself 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 on the background and the button recoils back to the surface of the mouse once you have taken the break.*"

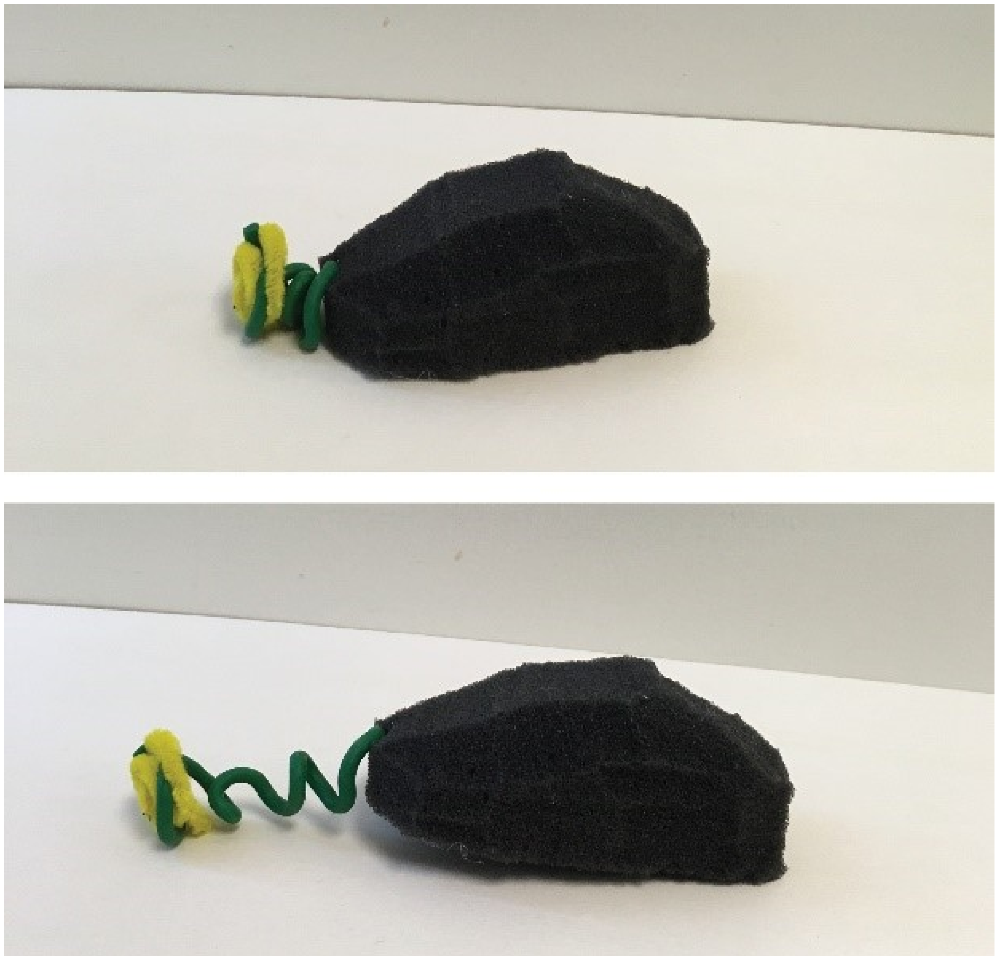


Figure 10: The mouse with a shape-changing attachment to demonstrate an object of the workplace as a design probe.

On the activity intervention scale, the object demonstrates two levels of intervention that covers the category of interruption and disruption.

Object of the workplace & Interruption

This design probe is positioned in the category C5 in the design space as described in Figure 8. The extending of the spring away from the mouse is the only change that happens in the environment of the user. This doesn't affect any other factor in the environment of the user and the suggestion is only through a visual feedback.

Object of the Workplace & Disruption

This design probe is positioned in the category C6 in the design space as described in Figure 8. The extending of the spring creates resistance in the mouse that prevents the user from continuing the computer-related work efficiently. This disruption may occur after the user ignores a few instances of interruption.

Between the two design probes and their ability to interrupt and disrupt to suggest a break, we manipulate the level of integration and the level of activity intervention of a shape-changing break reminder. Thus, encompassing opinions and impressions of having a shape-changing break reminder in different categories of the design space.

4.2.3 Phase 3: Participatory Design Session: Collective Dreaming About a Future Break Reminder

While describing their experience and giving their impressions on the design probes, participants often addressed features of the design probes that would not work for them, immediately following it up with improvisations that could work. We noted these instances in the design critique to initiate discussion during this phase. We began the design session by repeating these instances as questions. For example, "Earlier you mentioned that you wouldn't relate to a flower, is there an object, regardless of their shape change or interaction that you would relate to?". In answering these questions participants often started ideating objects that would work for them.

To facilitate further detailing to these ideas we asked questions derived from the different parameters and categories identified in the design space. For example, "Would you prefer an external object or object of the workplace as a break reminder? Would you want the break reminder to disrupt your work when you ignore it?".

In answering these questions, participants often explained the design of the object that they would like, expressing their preferences and discomfort with such a system.

4.2.3.1 The Prototyping Kit

The prototyping kit included a mix of elastic, and malleable material to ensure providing the participants with various possibilities of visualizing shape-through physical prototyping. The elastic materials included elastic bands, foam in the form of sheets, cubes, and rolls. For the malleable materials we had clay, and wires of different types. In addition to these, we had small rigid wooden blocks, tapes, glue to combine different materials. We also included markers, post its, and drawing sheets to provide the possibility of sketching during ideation

Figure 11: Materials provided to the participants for the participatory design session

4.3 Participants

We conducted the interactive session with 11 participants with Repetitive Strain Injury (Ages 21 to 56; Mean = 37.6, Median = 33). These participants had RSI for an average of

7.8 years. The symptoms varied from fingers, wrists, back, shoulders, and knees. Nine participants had consulted health experts for their condition and ten 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. We interviewed six participants in their workplace and asked five participants to get pictures of their workplace for the session. Nine participants had a desk and a cubicle of their own and two participants were moving between different work spaces.

4.4 Results

We transcribed the audio recording from the interview and coded the interview, the design critique, and the participatory design session separately. The codes were discussed with two other researchers to identify the general themes that emerged from the codes. For the participatory design session, we supplemented the codes from the audio transcription by interpreting certain salient design features that were not verbally expressed by the participants (for example, anthropomorphism, emotion as feedback). We present the results in of the interviews, design critique, and the participatory design session in separate sections below.

4.4.1 Analysis 1: Codes and Themes from the Analysis of the Interview

We identified six themes that emerged from 40 codes by conducting a manual thematic coding of interview transcripts (Figure 12). These six themes are: challenges and barriers, strategies to incorporate rest and movement, desire for more breaks, ergonomic devices, and aversion to notifications.

Figure 12: Codes and Themes from the Analysis of the Interview

4.4.1.1 Challenges and Barriers

This theme includes codes at instances where the participants mentioned the challenges and barriers faced while trying to take enough rest and stretch breaks. They perceived workflow as the biggest barrier to taking regular breaks (N=9).

> *P06: "I always feel guilty of the taking the time to do it because I have got so much work to do that, I just want to stay seated and get it done. I guess it the mentality that I need to get over."*

While mentioning about taking stretch breaks, 4 out of 11 participants felt that *Social Barriers* prevented them from stretching or taking frequent breaks at the workplace.

> *P02: "To be honest, I feel socially awkward doing the stretching. The height of the cubicle is such that if I stand, then almost upper half of my body is visible, and I don't like the idea of stretching when everyone around me can see me. If it was the long high partition, then maybe."*

In addition to barriers like workflow and the social environment, several participants (N=6) felt that it was challenging to remember to get up and stretch or just take a break. Being unable to regularly remember these things prevented them from maintaining good posture and incorporating stretch and rest breaks in their routine.

> *P11: "The challenge is to remember, to realize where your body is, if you are hunched over, it is so easy to get fully immersed and focused on something and your body is in a weird position and you don't realize it."*

4.4.1.2 Strategies to incorporate rest and movement

This theme includes all the codes at instances where the participants talked about strategies to incorporate health behavior such as rest and breaks. Several participants (N=9) mentioned that they switched their primary tasks with secondary tasks (such as getting water, visiting the washroom, or getting photocopies) to pause work and take a break. Few participants (N=4) tried to stretch while waiting during their peripheral tasks, such as in front of the microwave or the photocopier.

> *P07: "I do the microbreaks in the morning to get tea, get water. In the afternoon I don't. I should do that more."*

Only one participant was actively using a reminder system. Few (N=4) talked about having tried notifications and reminders earlier. When asked about how they currently scheduled regular breaks in their routine, 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.

> *P08: "Even if I sit down for an hour, I feel like my legs and back are not feeling great. So, I get up go to the washroom, get water. If I am in the middle of work and I ignore or forget but then within an hour or two, I start feeling the strain in my body and I have to get up."*

For the stretching, four participants had cue cards depicting the type of stretches to perform in the breaks. The ergonomic consultant provided these cue cards for the workspace, as a reminder. None of the participants reported actively using these cue cards and only two mentioned using it earlier. One participant mentioned scaffolding the cue cards with phone reminders to successfully do the stretches for a brief period.

4.4.1.3 Desire for More Breaks

Several participants expressed the desire to take more breaks that they were currently taking. While some expressed just the need to get up from their chair regularly (N=9), P07 and P11 expressed the preference for the break to incorporate healthy movement over a break from sitting on the computer.

> *P07: "I wouldn't want a break where I am getting up and going and sitting somewhere else. Maybe the break should be like a walking break."*

Four participants had a sit-stand desk in their workspace. One participant has a separate standing desk, they used it to read documents, they mentioned that dividing the task helped them to regularly switch between sitting and standing. Two others expressed the desire to take more sit-stand breaks.

4.4.1.4 Aversion to Notifications

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 to for awareness during the day rather than using every reminder to take a break. Others (N=3) had used it earlier but stopped because it was disruptive to the work and seemed too frequent.

P02: "Right now it's on my own, but initially I tried to use two different software. One was very disruptive, it was a cat that would pop up on my screen, asking me to take a break. It was funny initially and I would smile and go for a break. But when it was a deadline or some important thing and that showed up, I was frustrated. Then I got one with a small notification, it was less disruptive. These things what I find is that they break my focus sometimes and that I don't like."

When we asked them about if they would ever consider using phone or desktop notifications, several participants (N=7) were concerned that using a regular notification would disrupt their focus. Another interesting concern that a few participants (N=3) mentioned was that there were already plenty notifications to deal with.

P07: "Not every hour, it would be crazy. I already have enough notification to deal with and I don't want them to interfere with my work but something subtle,"

4.4.1.5 Ergonomic Devices as Support Systems.

This theme includes codes at instances where the participants mentioned the role of ergonomic devices in supporting them at work. Several participants (N= 8) used ergonomic devices to support better posture and breaks during work. These devices included ergonomic chairs (N= 8), sit-stand desks (N=4), vertical mice (N=1), and a document reader (N=1). Five participants had got an ergonomic adjustment of their workspace where the height adjustments of their work desk and monitor. All eight participants perceived ergonomic adjustments effectively mitigate their symptoms.

Participants who had got an ergonomic evaluation mentioned that getting personalized feedback on their work habits and posture had helped them to be more aware of their work habits.

4.4.2 Analysis 2: Codes and Themes from the Analysis of the Design Critique

At the end of interview questions, we introduced the two design probes discussed in Section 4.2.2.2. We asked the participants how they would feel about having design probes as break reminders in their workplace. We present their impressions as general preferences and a comparison between their impression of the flower and the mouse as both interruptive and disruptive shape-changing break reminders.

4.4.2.1 General Preferences

Based on the impressions of the participants 23 codes emerged. We further grouped these into four themes: aversion to disruption, emotional engagement, pragmatic values, and aesthetic values (Figure 13).

4.4.2.1.1 Aversion to Disruption

This theme included codes at instances where participants mentioned that notifications for regimented breaks would not or have not worked for them. It had the largest number of codes (10). Participants critiqued the design probes and suggested improvements for the probes such the reminder is less disruptive to their work.

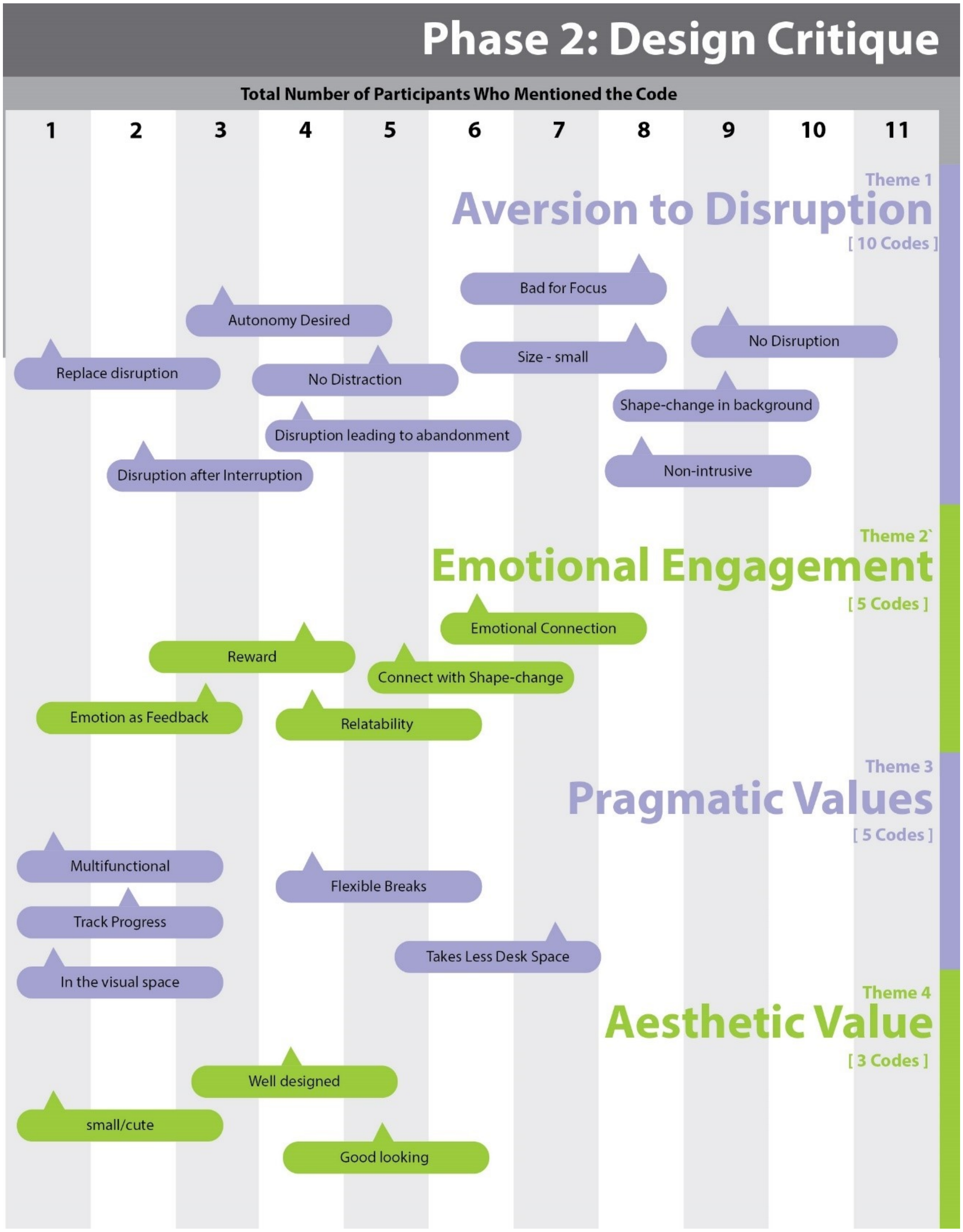


Figure 13: Codes and Themes from the Analysis of the Design Critique

The participants (N=9) mentioned the advantage of the external object (i.e. the flower) of having the shape change in the background. On the contrary, shape change in the object of the workplace (i.e. the mouse) would mean that it is still in the near periphery of the user while working. While participants acknowledged the advantage of good visibility, they perceived it intrusive and potentially annoying in the middle of work.

P02: "I would prefer the flower because that it is less disruptive, I don't like to lose focus while I am doing something important. It (the mouse) has the tendency to annoy me."

Another suggestion toward making the break reminder less intrusive was to make it smaller in size (N=8). This was seen possible with the external object and not with the object of the workplace.

P09: "If something pops on my screen, in the middle of writing an email, I would close it and forget about it later. So, if you have the object there, it would be better. I don't think I would be annoyed if it wasn't too big."

While a greater number of participants were completely averse to having disruption (N=9) of any kind in a break reminder, two participants agreed that the system could become disruptive if that had not engaged in any movement for a long time and ignored several instances of interruption.

P02: "If it becomes disruptive after day 4 hours of not getting up then it is fine because I am personally finding that I should be standing up after at least every two hours, but 3–4 hours is maximum, that I should get up from my chair."

Participant 11 perceived that the shape change in the mouse creates a negative feedback loop and is not desirable.

> *P11: "It creates a negative feedback loop right, where I am doing something not because it is good for me but to get rid of this annoyance. So, that would be my concern about that."*

4.4.2.1.2 Emotional Engagement

Several participants (N=6) mentioned that the need of *Emotional Connection* with the object was important in order to listen to what the object is suggesting without being annoyed.

> *P04: "It can be something else, depending on the individual, what speaks to them. If it is psychological, it depends on what really affects you, right."*

Participants (N=2) also mentioned *Relatability* with the shape change as a determinant factor for emotional engagement with the device. A shape changes in an inanimate object such as the object of the workplace (for example the mouse, the monitor, or the keyboard) were harder to relate, compared to a flower.

> *P02: "If I compare, flower related to nature which I like. So, I can relate to that in real life. But the shape changes on a physical computer, I would not connect to it that much."*

4.4.2.1.3 Pragmatic Values

This theme includes codes at instances where participants expressed practical concerns of including the device in their workplace. This included the need for the object to require less desk space (N=7), the ability of the device to allow flexible breaks (N=4), the need for the device to be multifunctional (for example a clock that is also a break reminder) (N=1), the ability to track progress over a period (N=1), and the object to be in the visual space of the user (N=1).

4.4.2.1.4 Aesthetic Values

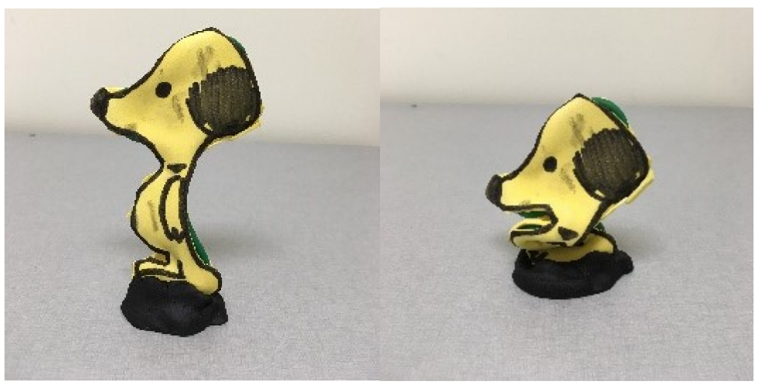
The design probes were intentionally crude to make them easier to critique, this also led the participants (N=5) to emphasize that the *aesthetics* of the object was important for them to accept it in their environment.

> *P02: "To be honest, I would like it if it looks good. I already have small stuff on my desk, if it is a well-designed product, I will keep it. I like the fact that it's not intrusive. I don't like big objects, but small, yes for sure."*

4.4.3 Analysis 3: Codes and Themes from the Analysis of the Participatory Design Session

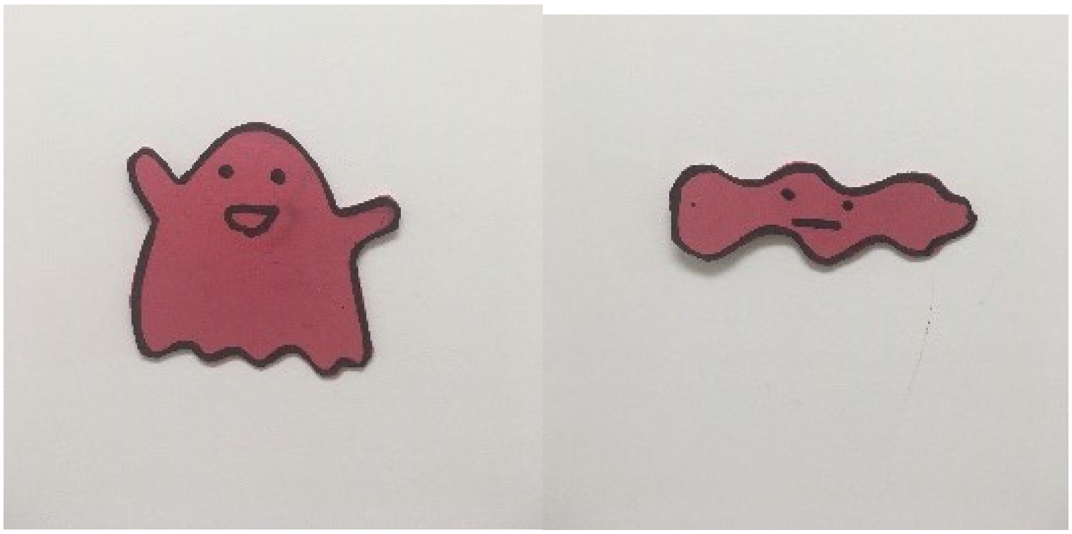
At the end of the Design Critique we asked the participants to ideate and prototype a break reminder for themselves. Nine participants agreed that they would like to have a tangible break reminder of their own choice. They made physical prototypes described in Table 1. One participant (P01) mentioned that they were happy with their outlook reminders and did not find a shape-changing break reminder desirable for them. They mentioned concerns about desk space and a personal preference of not having any extra objects in their workplace. Another participant (P10) mentioned that they really liked the flower and would not want to design anything as the flower would work well for them.

Table 1: Prototypes Generated during the Participatory Design Session

Prototype Description
PROTOTYPE P02  **Description**: The physical model of snoopy 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. **Design Strategies**: • *Pragmatic Values* — Repurpose an existing object on the desk. • *Emotional Engagement* — Favorite character suggesting break. • *Physical Properties* — Aesthetics of a preexisting object that is already appreciated. **Design attributes**: Shape-changing object. External to the workplace with non-intrusive interruption.

Prototype Description

PROTOTYPE P03



Description: An animated character that is pinned on the board. It is happy in the default state. 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.

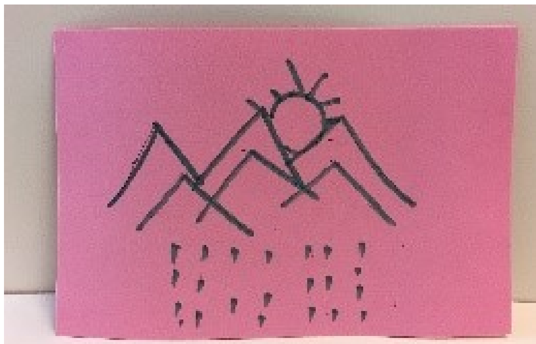
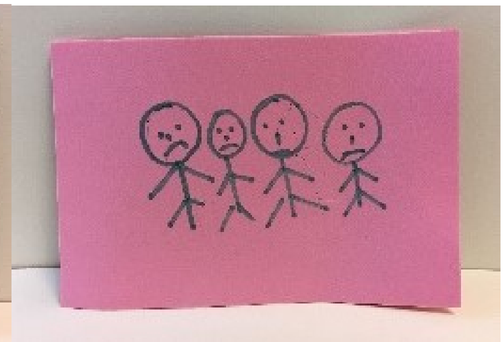
Design Strategies

- *Pragmatic Values* — Pinned to the wall for lack of desk space.
- *Emotional Engagement* — Represents participant interest in cartoons. An object that one needs to take care of.
- *Physical Properties* — Aesthetics of a preexisting object that is already appreciated.

Design attributes: Shape-changing object. External to the workplace with non-intrusive interruption.

Prototype Description

PROTOTYPE P04

Description: A painting that displays a utopian image (like a 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 the user is back from the break, the default state is presumed again.

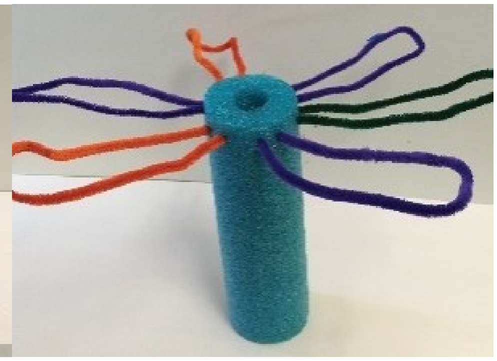
Design Strategies

- *Emotional Engagement* — The transition from utopia to dystopia was representative of the body that persuades the user to take a break
- *Physical Properties* — The choice of utopian and dystopian image reflected the personal preference of the participant.

Design attributes: Display device. External to the workplace with non-intrusive interruption.

Prototype Description

PROTOTYPE P05



Description: The bicycle (top) transforms 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 behavior; 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 behavior is resumed

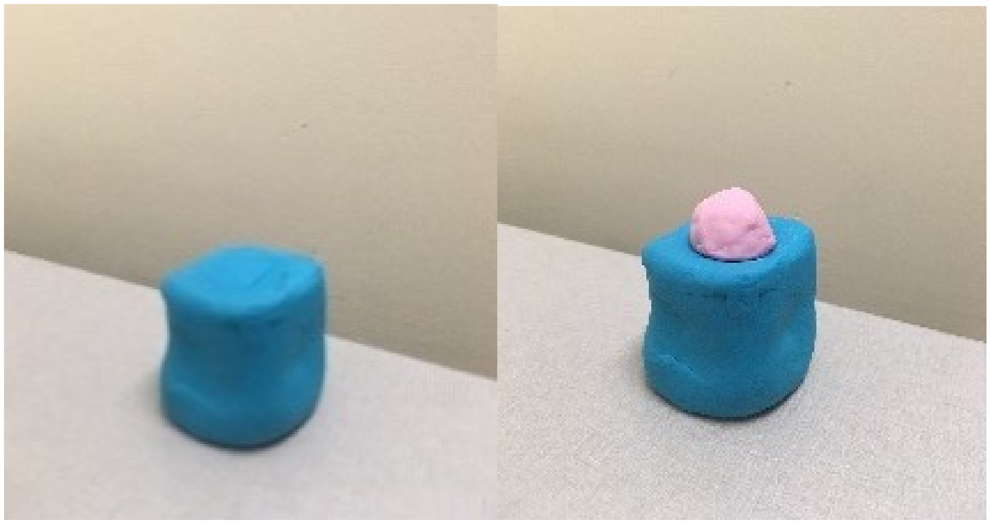
Design Strategies

- *Emotional Engagement* — New objects every week to avoid boredom and continue engaging with the object.
- *Physical Properties* — The choice of objects based on environment-friendly preference of the participant.

Design attributes: Shape-changing object. External to the workplace with non-intrusive interruption.

Prototype Description

PROTOTYPE P04



Description: A cyan colored cube (top) that sits on the desk in the default state. When it is time to take a break, a light emerges out of the cube (bottom). Once, the user is back from the break, it goes back to a generic cube again

Design Strategies:

- *Pragmatic Values* — Small for potability, generic of social acceptability.
- *Physical Properties* — The aesthetic (color) based on personal preference.

Design attributes: Shape-changing object. External to the workplace with non-intrusive interruption.

Prototype Description
PROTOTYPE P07  **Description**: A bright-colored 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. **Design Strategies** • *Emotional Engagement* — Absence of continuous motion persuades the user to act. • *Physical Properties* — Toy-like appearance for playfulness and rotation discontinues in the periphery. • *Pragmatic Values* — Small for space concerns, bright colors for catching attention. **Design attributes**: Tangible object with rotation capabilities. External to the workplace with non-intrusive interruption.

Prototype Description

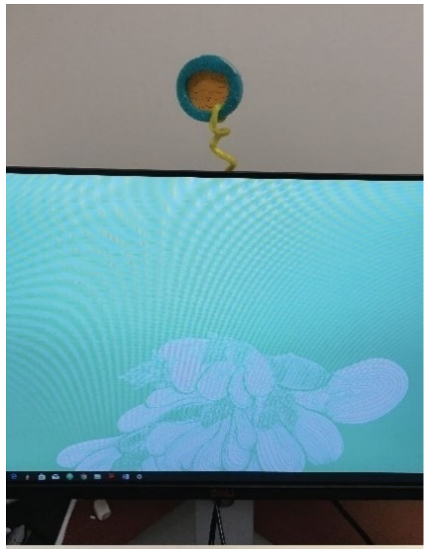
PROTOTYPE P08

Description: A superman 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.

Design Strategies

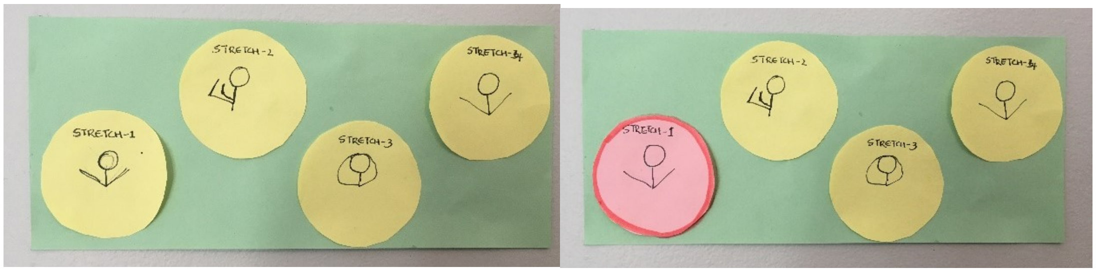
- *Emotional Engagement* — Favorite character to represent personal preference.
- *Physical Properties* — Subtle change in posture for interaction in the periphery, visually appealing to the participant.

Design attributes: Shape-changing object. External to the workplace with non-intrusive interruption.

Prototype Description
PROTOTYPE P09  **Description**: A tiny frame with the picture of the ocean is hidden behind the monitor. When it is time to take a break, it slowly moves up to become more visible to the user to remind of positive things. Once the user is back from the break, it goes behind the screen again **Design Strategies** • *Emotional Engagement* — The picture of the ocean represents positive emotions for the participant. • *Pragmatic Values* — Pinned to the monitor for space concerns. • *Physical Properties* — Color of the frame reflects personal preference **Design attributes**: Shape-changing object. Attached to the object of the workplace with non-intrusive interruption.

Prototype Description

PROTOTYPE P11



Description: A set of stretches displayed on horizontally aligned circular buttons on a rectangular display device. When it is time to take a break, a button lights up, suggesting doing that particular stretch. When the user has performed the stretch suggested, they can press the button and the light goes off.

Design Strategies

- *Pragmatic Values* — Pinned to the wall, Off-load decision-making to choose an exercise, useful breaks.

Design attributes: Tangible User Interface. External to the workplace with non-intrusive interruption.

4.4.3.1 Design Strategies

We coded the design strategies applied by the participants. In total, 12 codes emerged, we clustered them into 3 higher level themes. We counted the number of participants that used each strategy. We discuss the codes based on themes, in the order of prevalence.

4.4.3.1.1 Physical Property of the Device

This theme included all the codes that determined the physical attribute of the object such as appearance, color, texture, or size. As shown in Figure 14, *Feedback in the Periphery* and *Aesthetic Value* were present in 8 out 9 prototypes. Participants often mentioned the need to have the object not to disrupt their work and have the aesthetic quality that enables them to accept the object in their workplace. The need for an aesthetically appealing product also reflected in the frequent occurrence of the code *Reflects Personal Preference* (N=7). We often found a strong correlation between the personal preference of the user and the device they made in the design session. For example, P02 chose to have snoopy as the break reminder because it was their favorite character, P03 made an animated character and we observed that they owned a few personal objects with visuals of similar animated characters, P09 made a small frame with the picture of the ocean because they grew up next to the ocean and it reminded them of positivity and home.

> *P03: "As I am talking, I am realizing that a flower withering wouldn't affect me so much. I would be more invested in a character or a pet I could take care of, I would care a little bit more."*

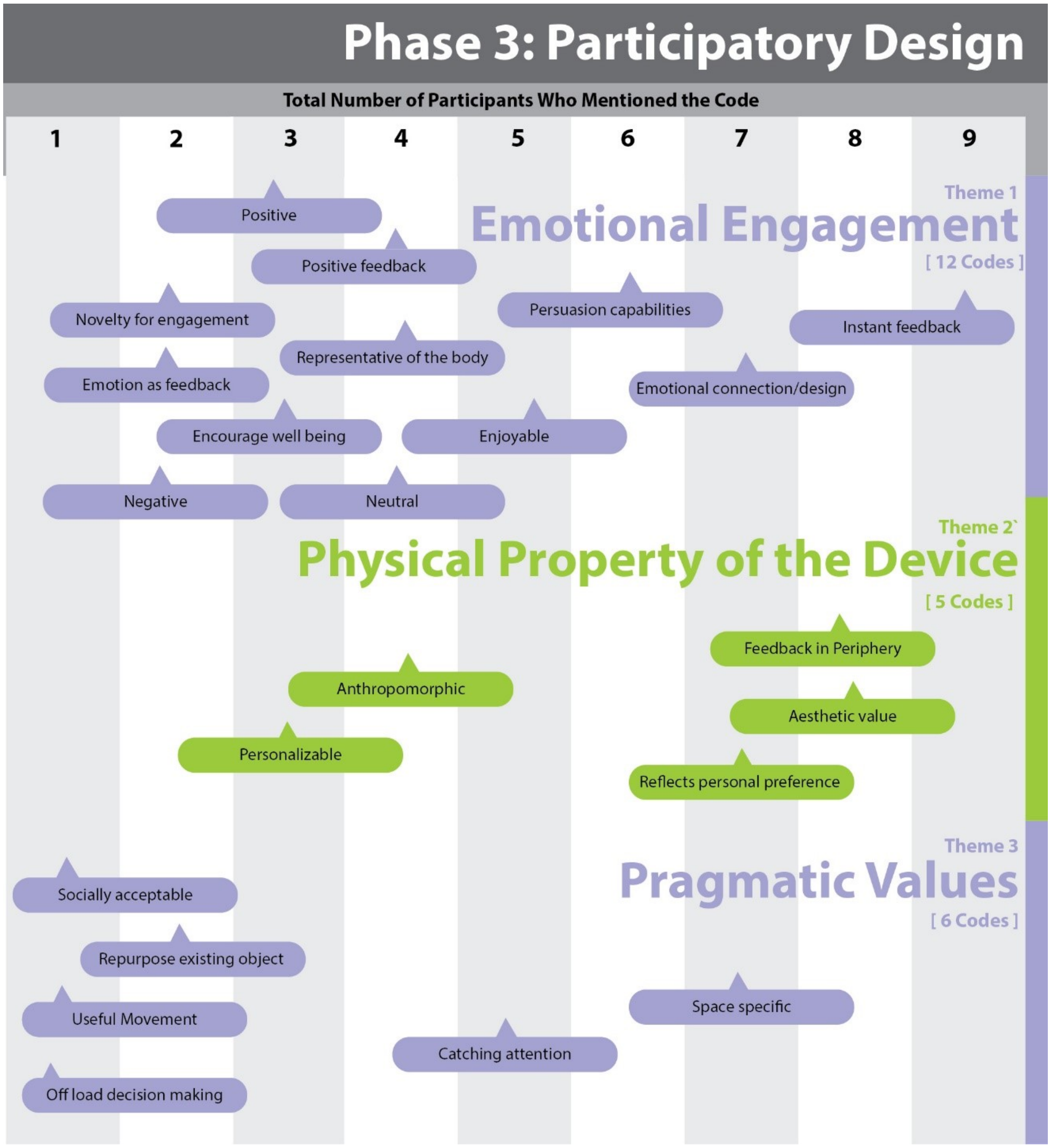


Figure 14. Codes and themes that emerged in the participatory design session

Several participants used anthropomorphism (N=4) to depict emotions (P02, P03), persuasion (P02, P03, P08), and motion (P02, P07, P08).

> *P08: "I feel like the superman is more interesting and would push me more to take a break. If I have that, I would see it like superman thinks it is breaktime. So, I should get up."*

Three participants (P04, P08, P09) thought about the possibility and importance of making the object easy to *Personalize*. This code primarily came up when the object was strongly based on the participant's personal preference but also has the ability to adapt to other people's preferences.

> *P09: "For me it is better to have a possibility of putting the picture. So, there is a device and there is an option to personalize it."*

4.4.3.1.2 Emotional Engagement

This theme included all codes that addressed the relationship between the user and the object. It had the greatest number of codes (10/21) between the three themes. All participants who agreed to design a device for themselves (N=9) mentioned the need for an *Instant Feedback* when they returned from the break.

The feedback varied from animate characteristics like changing emotions of the object when the user returned from the break (P02, P03, P08), resuming the state of motion of the object (P05, P07) to inanimate characteristics like change in peripheral visibility of the object using light or position of the object (P04, P09, P11).

Several participants mentioned the *Emotional Connection* (N= 7) with the object as an important factor to effectively listen to the object when it asks them to take a break.

> *P09: "I am thinking of a sun that comes out of your screen. Something positive, something that reminds you of a nature. Some people would like a cat, not me."*

Several participants (N=7) expressed that they perceived the default state of the object as the normal state and when that changed to suggest the break, there was an urge to resume the normal state. This *Persuasion Capability* of the object was an important factor to nudge them to take a break. In the following quote by P03, we observe a combination of *Feedback in the Periphery, Emotional Connection,* and *Persuasion Capability* as design strategies.

> *P03: "Something like a shape or a character that I have to take care of while taking care of myself. It doesn't catch my attention but when I look around, I notice that the cat or the character is sad or dying or just sad and I would want to take a break to make it not sad."*

Other codes in this theme were *Enjoyable* interaction (N=6) with the device, which meant that the participants looked beyond the functionality of the device, for example: not intrusive but still visible, space occupied in the workspace. In this code, participants did not expect the device to merely work well but also to delight them.

> *P06: "It is almost like having a little play thing in your desk."*

> *P07: "It could be a toy character; I would like superman. If there could be an additional feature, like the cape that I could take off. I would play with it when I am looking at the screen and thinking"*

Other instances of Emotional Engagement included *Positive Feedback* as a reinforcement to taking more breaks. These included objects emoting positivity (P02, P03), depiction of positivity through pictures (P04), and facilitation of feeling of accomplishment (P09).

Four participants used the state of the object as a *Representative of the Body* to remind them of the consequences of prolonged sitting.

> *P05: "An ideal world to an apocalypse would definitely work for me. It is just the journey, it could be any journey, here it is representing something positive to negative right."*

The nine prototypes can be categorized into positive (2/9), negative (3/9), and neutral (4/9) in terms of the feedback provided during the break. For example, the snoopy becoming sad (P02) has a negative connotation to it, the frame of the beach (P08) appearing to suggest a break has a positive connotation to it, and the device to suggest stretches (P09) is utilitarian and has a neutral connotation in terms of the feedback.

4.4.3.1.3 Pragmatic Values

This theme included all the codes that addressed strategies employed to add pragmatic value to the object. Several participants (N=7) designed *Space Specific* objects with respect to their workplace. Participants with less space on their desk wanted objects that could be pinned on the pin board or attached at the back of their monitor. Participants also mentioned the need to have a small object. Even though visibility was a general concern, they did not express the need for a bigger object.

> *P11: "If it is not pinned on the wall, the way I would see it is another object taking up space on my desk and space is a premium here. If you don't have a clear desk, that is another hurdle to do the exercise that you are looking for."*

With regards to visibility, participants (N=5) mentioned the importance of the object *Catching Attention* when it is time for a break. While some used light and motion, the position of the object in the workspace varied on the spectrum of being not intrusive at all, leaving the user to look at it when they want to be noticeable such that the user is aware of the change.

> *P09: "I am thinking that it has to catch the attention of the user and make that connection of what is in the picture with taking care of yourself, taking out the time, stretching."*

Participants (N=2) also chose to *Repurpose Existing Objects* in their workplace. P02 chose to add the functionality of standing up and smiling in the default state and collapsing down to suggest as a break to a model of Snoopy they already had on their desk.

4.5 Summary

We conducted Interactive Sessions with 11 people with RSI. We present the results as themes that emerged in the three phases, the Interview, the Design Critique, and the Participatory Design Session. Figure 15 illustrates the themes that emerged.

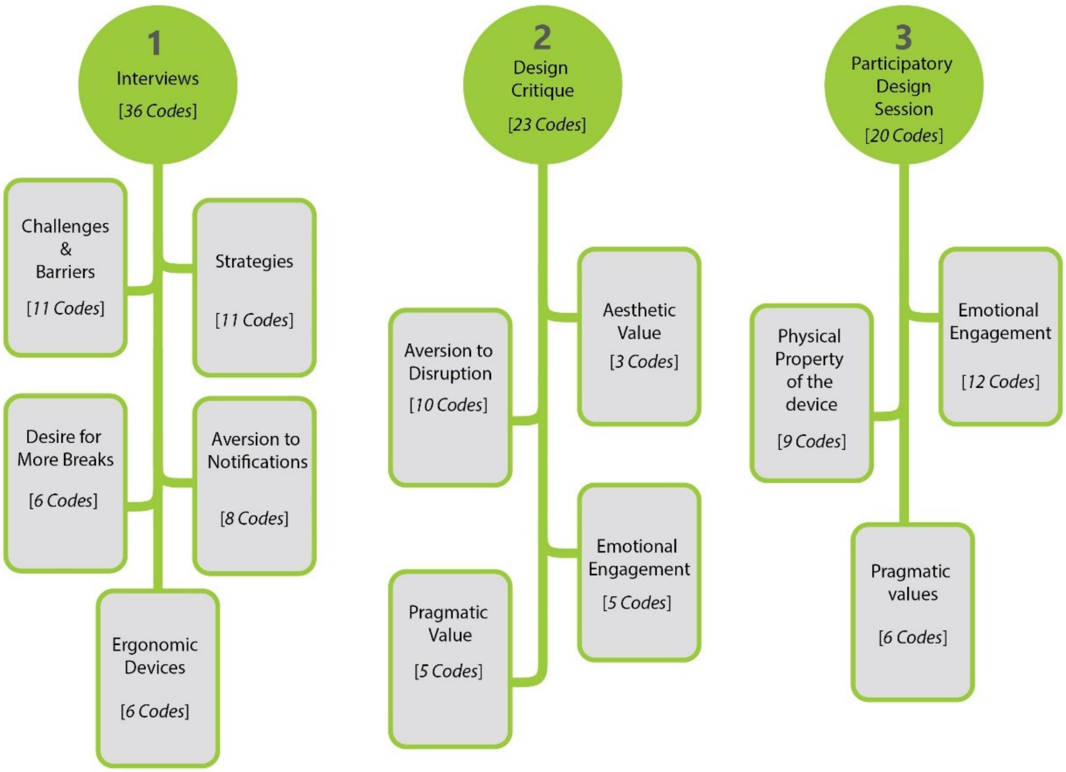


Figure 15: Summary of the themes that emerged in the three phases: the Interview, the Design Critique, and the Participatory Design Session

The results from the interview show that all participants with RSI were aware of the health behavior and were actively trying to incorporate breaks and exercises in their workday. Workflow and social factors were the biggest barriers in successfully taking enough rest and stretch breaks. Although the desire for more breaks was consistent across all participants, the inadequacy of generic reminders made it difficult to use them to incorporate more breaks. Instead participants often modified their primary and peripheral tasks to incorporate more movement and relied on their bodies to tell them to take a break.

While demonstrating the design probes, participants showed a strong aversion to disruption. They perceived the shape-changing capabilities of the mouse to be intrusive to work. On the contrary, there was a strong preference towards the flower as it was ambient, and the withering action was relatable. Through suggestions of improvement in the design probe, participants expressed the desire to emotionally engage with the object by suggesting replacing the flower with an object of their personal preference. In order to accept the physical artefact in the environment, the participants emphasized that the probes should have certain aesthetic quality and also meet the pragmatic constraints such as space availability.

The design strategies applied by the participants in the participatory design were in congruence with the general preferences expressed while giving their impressions on design probes. The physical property of the device was the most prevalent theme encompassing the interaction (for example, the nature of feedback) and the appearance of the device. While ideating, participants showed a strong inclination toward making the object less intrusive (except P09). There was a strong preference to emotionally engage with the object by using strategies such as emotional feedback and persuasion capabilities.

4.6 Discussion

Our results show that participants perceived workflow and social barriers in incorporating appropriate breaks and rest in their workday. They demonstrated an aversion to external disruption during work, especially in the case of break reminders. Lastly, they expressed the desire to emotionally engage with the device. Incorporating shape-changing capabilities in tangible breaks reminders shows tremendous potential as they can be less disruptive by being in the periphery and facilitate emotional engagement through their capability to evoke positive emotions by simulating organic life-like movements.

4.6.1 Organizational Factors

In the interview, many participants talked about social barriers as a deterrent to taking enough rest and stretch breaks. These social barriers included the awkwardness of being seen by colleagues while performing exaggerated stretching movements. In addition to that, the apprehension of being caught in the moment, not working, was also seen as a social barrier.

While such social factors discouraged the participants from incorporating healthy behaviors, other elements of social and organization support acted as a facilitator for the same. P09 mentioned that explicitly putting pictures of stretches at the photocopier meant that there was nothing absurd about stretching while waiting for the copies. Other organizational factors that played a key role in awareness and action by the participants was the availability of a system to consult experts and get the prescribes ergonomic adjustments. P11 mentioned that they moved from the previous workplace with these problems and a system of getting the ergonomic assessment in place encouraged them to take on this opportunity proactively at their current workplace. P01 mentioned living with RSI for about 20 years and applied for the evaluation recently after seeing a coworker getting it done.

The role of psychosocial factors such as like anxiety [2,63], mental exhaustion [27], social support [48], work organization [17], and time pressure [8] in exacerbating RSI has been discussed in the literature. While this is outside the realm of design of break reminders, the success of the device in supporting the user to successfully rest and break is intertwined with social and organization support. Actions at the organizational level to normalize the practice of stretching, taking breaks and the ease of access to consultants and ergonomic adjustments can evidently increase the instances of proactive behavior amongst employees.

4.6.2 Personalization of Tangible Objects

Through their critiques of the design probes and strategies in ideating a break reminder, participants showed a strong inclination toward personalization. This was reflected in the relationship between the user and the object (emotional engagement), the physical appearance of the object (reflecting personal preference and aesthetics). If we compare, most of the designs (except P04 & P11) had more animate characters than the probes provided in the design critique. For example, external objects such as Snoopy (P02), an animate blob (P03), or Superman (P08) show more animate characteristics than the flower. Similarly, for objects of the workplace, a tiny frame with a picture of the ocean communicates more emotions than a basic spring mechanism attached to the mouse in our probe. As participants desire more character and communication from the device, the need to personalize these features becomes more critical. As a flower maybe be more ubiquitous hence more acceptable than a figurine of a specific character.

This preference of persuasion over coercion demonstrates that the need to emotionally engage with the object is important it is to able to effectively persuade. In other words, the user should first care about the physical object to care about the digital information the object embodies. Reiterating P04, if the object has to have a psychological impact, the objects to speak to the user.

4.6.3 Facilitate Healthy User-Object Relationship

Our results show that for the device to be effective, it is important to the use to emotionally engage with. Participants preferred the probes that they could imagine having a positive experience with. For example, the flower withering nudged them to care and save the flower from withering. The design session reinforced this preference, participants designed devices that initiate positive feedback, encourage well-being, and providing them with a sense of accomplishment. The shape-changing attachment to the mouse was less desirable as it was more disruptive to work, compared to the flower.

To enable this positive relationship and emotionally engage with the object, a strong preference for the reminder to be less disruptive emerged. In addition, aversion to disruption, the interaction with the device should also evoke positive emotions in the user. Thus, reinforcing the healthy user-object relationship.

4.6.4 Pragmatic Concerns of Adopting the Device

We conducted the session either in the workspace of the participants or asked them to bring pictures of their workplace with them. We designed the session and questions so that they are thinking about their work space throughout the session. While critiquing the design probes and designing a break reminder for themselves, the participants considered pragmatic constraints of their own workspace that would determine if the device can successfully exist in their work environment.

A major constraint was the lack of desk space or the presence of a plethora of work objects that could obliterate the visibility of the shape-changing break reminder. This led to design strategies such as pinning the device on the board (P03, P11) or attaching it at the back of the monitor (P09). Another strategy was to make the object small so that it can sit close to the visual space of the user but is not big enough to be intrusive. Interestingly, the size of the object affected the level of disruption. Big objects were seen to be more intrusive than small objects.

The social acceptability of the such objects also determined the type of objects the participants designed in some cases. While this may not hold true to all workplaces, users in more conservative workspaces may be hesitant to have a playful object on the desk. P04 designed a generic blue cube in their favorite color. This is interesting also because they wanted to not have a playful character to avoid attention but still associate with the object by using the color of their choice.

4.6.5 Relevance of Shape-Changing Devices

We introduced the design probes with shape-changing capabilities for the design critique to familiarize the participants about the concept and possibilities of shape-changing devices. From the results of the participatory design session, we see the prevalence of shape-changing devices (N=7). The participants used the ambient motion of shape-change to simulate emotions, manipulate visibility, and transform the physical form for novel. These results demonstrate that in addition to the advantage of shape change being an effective way of peripheral feedback, they can also establish a relationship between the user and the device.

4.7 Limitations

We recruited several participants by getting in touch with the ergonomist that has provided consultation with them. Eight participants had their own cubicle with a large desk space. Hence, our results could have been more biased towards people who have enough desk space and accessible facilities for ergonomic consultation and adjustments. While it is crucial to conduct the user study in their work environment, in some cases, the participants were in a hurry to get back to work and provided the research with succinct responses. In the first couple of studies, participants were hesitant to get involved in prototyping and look for materials in the box. We changed this for the rest of the study by laying out material on their desk to make things easier to grasp, at the beginning of the participatory design session. While the probes were crucial to introduce the participants to the concept of shape-changing devices, they could have primed them toward designing a shape-changing or tangible device.

The study is an exploration understand the challenges, needs, and desires of people with RSI, during taking breaks. While the results present an analysis of their articulation, it does not address the gulf between what people think and what they actually do. By structuring the session from a descriptive interview to an imaginative design session, we tried to make them introspect about their own habits and experiences before they design something. However, a long-term investigation of an implemented technology can validate these findings.

Chapter 5: Design Recommendations

Based on the results and discussion presented in chapter 4, we propose the design guidelines for break reminders for people with RSI. While the results are derived from the study of workplace with users working on the computer, some of these guidelines might be relevant to other workspaces that offer the possibility of having a tangible object as a break reminder and require non-intrusive solutions.

5.1 Object as an Extension of the User

The first thing the user noticed about the object is its appearance, hence to for the user to accept the object it should be aesthetically pleasing. Additionally, for the user to appreciate the object, it should also reflect their personal preference. The tangible device sits in the workspace, often with other personal objects of the user. These personal objects are representations of the users, their preferences, and personalities, hence an extension of themselves. The physical appearance of the break reminder should effectively satisfy these criteria to be accepted in the workspace of the user.
Addressing user preferences and personalities requires a high level of customization for these break reminders to effectively engage with the users. With the increasing popularity of DIY fabrication and assembly [77], it is possible to provide users with resources that give them the autonomy to manipulate different factors such as the level of integration (objects of the workplace or external objects), the level of activity intervention (interruption or disruption), and the aesthetics (color, texture, form). Thus, democratizing technology by providing the resources to the users to decide what the break reminder could be.

5.2 Shape-Change for Peripheral Feedback

We can address the aversion to disruption by providing peripheral feedback to the user. Calm technology such as light, color, and shape-change can provide peripheral feedback. Humans are sensitive to stimuli (such as change color and shape, or motion) in their near and far periphery. However, research shows that between these different stimuli, people are most sensitive to motion in the far periphery [33].

The perception of the periphery in the context of break reminders varies between different users. This suggests that the object could be anywhere between the near and far periphery of the user, in their workplace. To ensure noticeability in the case of far periphery, motion can be the most effective method. Shape-changing capability can address the need to facilitate motion in tangible break reminders. Through their ability to change physical factors like orientation, form, volume and texture, [67] they can act as effective stimuli in a break reminder at the workplace.

5.3 Shape-Change to Engender Emotional Engagement

The user should be able to emotionally engage with the object in order to be persuaded to act when the device suggests a break. To establish this meaningful connection, interacting with the device should evoke positive emotions in the user.

By simulating organic, life-like movements, shape-changing devices are capable of both embodying and engendering emotions [67]. Shape change as an external movement can change the internal processes of the user, i.e. evoke emotions of self-care and well-being, thus, motivating them to act towards their goal of taking rest and stretch breaks.

5.4 Space Constraints

The space constraints of the workspace of the user determine the space occupied by the object. If the object sits comfortably on a clean desk, if it is pinned on the wall, or attached to the computer device. The constraint of the workspace is an important factor to consider because even if the object is well designed, non-intrusive, and speaks to the user, it is difficult for it to be adopted if it does not address the requirement of the space in which it desires to exist.

Chapter 6: Conclusion and Future Work

This thesis explored the intersection of workplace related injuries, shape-changing devices, and participatory design. We conducted an ideation session with HCI professionals and interactive sessions with people with RSI for this exploration. In this chapter we present the conclusion and future for this thesis.

6.1 Conclusion

Through our ideation session we identified 6 categories of tangible devices that could support workplace related injuries during computer work. These categories were based on the type of object (i.e. object of the workplace or an external object) and the type of intervention (i.e. passive, active interruption, or active disruption). We select 4 out of six categories to as an opportunity space for shape-changing break reminders and used it future session with end users. The intent of this study was to understand the design space with people familiar with the field and use the knowledge to inform the sessions with end users.

We conducted the interaction session with people with RSI to identify their challenges of working with RSI, to understand their preferences and desires from a break reminder, and to investigate the potential of shape-changing devices in this context. We structured each session in three phases: 1) the Interview; 2) the Design Critique; 3) the Participatory Design Session. The results from the interview show that participants were actively trying to incorporate break and movement during their workday. In this process they experienced workflow and social factors as barriers, and they were not satisfied with existing notification systems to regulate their break-taking habits. They usually modified their primary task to incorporate rest and break during their workday. These answers our research question of identifying the challenges and strategies that people with RSI face while incorporating health behavior at work.

The results from the design critique demonstrate that participants had an aversion to elements of disruption, and they showed an inclination towards emotionally engaging with the object and practical constraints of the workplace as a concern to adoption of the device. This captures the impressions of the participants about probes from the four categories identified in the ideation session and answers our second research question. The participatory design session reinforced the preference of emotional engagement and pragmatic concern in addition to emphasizing the physical properties of the device (such as form, size, appearance). The desire for the device to be less disruptive and emotionally engaging answers our overarching question about the potential of shape-changing devices for people with RSI. Shape-changing devices can be an effective solution because in addition to effectively providing passive awareness to the user, shape-change can also engender emotions and hence enable emotional engagement with the device.

6.2 Future Work

Our results show that users are inclined towards emotionally engaging with tangible break reminders in the workplace. In our observations, we saw the presence of personal objects with aesthetical function in various workplaces. This demonstrates potential for personal objects to serve more than an aesthetical purpose, they can become peripheral objects that provide passive awareness to support user's goal. While this work was conducted with people of RSI, who were actively putting efforts towards having healthy work habits, the insights can extend to provide support to all office workers trying to achieve similar goals. Perhaps, the application could extend beyond break reminders, through further investigation, to applications that require supporting different goals through providing passive awareness to users.

Future work also includes deploying a shape-changing break reminder for a long-term study. In addition to the appearance and the type of shape-change, it would be important to do multiple iterations during the usage period to support long-term motivation. These studies would be crucial to go beyond the analysis of articulations of the user, to address the gap between what users think and what they do.

Appendices

Appendix A: Interactive Session with People with RSI

A.1 Consent Form

Project Title

Shape-changing Devices for Carpal Tunnel Syndrome Rehabilitation

Project Sponsor and Funder (if any)

Tri Council - NSERC CREATE - CUResearch107243

Royal Society - CUResearch106951

Carleton University Project Clearance

Clearance #: 109293 Date of Clearance: December 19, 2019

Invitation

You are invited to take part in a research project because your experience with repetitive strain injury. The information in this form is intended to help you understand what we are asking of you so that you can decide whether you agree to participate in the interview. Your participation in this study is voluntary, and a decision not to participate will not be used against you in any way. As you read this form, and decide whether to participate, please ask all the questions you might have, take whatever time you need, and consult with others as you wish.

What is the purpose of the study?

We are conducting an interview. Please be assured that the researcher will provide all the information required to participate in the study and will be available for assistance during the study.

If you agree to take part in the study, we will ask you to:

Answer specific questions about your experience of living with repetitive strain injury.

Answer specific questions about modification in your workplace that work or do not work for you.

At the end of the interview will show you some low fidelity prototypes.

You will be asked for design suggestion for the same. You can choose to use the materials with the researcher to describe your suggestions.

Possible Benefits

You may not receive any direct benefit from your participation in this study. However, your participation may allow researchers to better understand the design requirements for shape-changing interfaces for hand rehabilitation.

Compensation/Incentives

You will be compensated with 30 CAD for your time

No waiver of your rights

By signing this form, you are not waiving any rights or releasing the researchers from any liability.

Withdrawing from the study

If you withdraw your consent during the course of the interview, all information collected from you before your withdrawal will be discarded.

Confidentiality

You will be assigned a code so that your identity will not be directly associated with the data you have provided. All data, including coded information, will be will be kept in a password-protected [or encrypted] file on a secure computer. If you choose to be photographed, your face will be blurred to avoid any identification.

Data Retention

Your de-identified data will be retained for a period of 2 years and then securely destroyed. The audio recording will be collected using pseudonym and will be stored and destroyed with other data.

New information during the study

In the event that any changes could affect your decision to continue participating in this study, you will be promptly informed.

Ethics review

This project was reviewed and cleared by the Carleton University Research Ethics Board B. If you have any ethical concerns with the study, please contact Dr. Bernadette Campbell, Chair, Carleton University Research Ethics Board (by phone at 613-520-2600 ext. 4085 for CUREB B or by email at ethics@carleton.ca).

A.2

Questionnaire

Age __________

Gender

Male	Female	Non-binary	Prefer not to answer

How long have you had repetitive strain injury for?

What is the type of problem faced in the body during and after work?

When did it start? How much has it gotten better or worse with time?

What methods of relief have you tried?

What kind of challenges do you face at work?

Did you consult anyone about these problems? What were the suggestions made?

Do you face any challenges in following these suggestions on a regular basis?

How have you modified your workplace to suit your needs?

What do you think about these devices?

What do you think about these objects

Mouse with shape-changing capabilities

An independent object with shape-changing capabilities

What should such an interactive device do to best support you at work?

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