THE UNIVERSITY OF CHICAGO

FOCUSHIFT: ACTUATED INTERVENTION TO PREVENT SMARTPHONE OVERUSE VIA PHONE-ATTACHED SHAPE-CHANGING DEVICE

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ABSTRACT

With instant gratification constantly available at the tap of a screen, smartphone overuse has quickly become a widespread problem. Many digital applications have been built to combat this issue, either by blocking content entirely or by asking users to pause and reconsider before entering a distracting app. In this paper, we propose FocuShift, a shape-changing device that attaches to the phone case, as a novel tangible intervention to prevent smartphone overuse. Our device is designed to trigger a shape-change intervention periodically while a user is engaging with a distracting app, altering the ergonomics of the phone and promoting awareness while distracted. We deployed our device in-the-wild for a 48 hour study, comparing screen-time between baseline phone usage and phone usage with our shape-changing intervention active. We then conducted interviews with participants to understand the qualitative merits of our proof-of-concept.

CHAPTER 1
INTRODUCTION

1.1 Motivation

In today's attention economy, smartphone apps are monetarily incentivized to capture and hold the user's focus for as long as possible. Moreover, smartphones are designed with ease of use in mind, resulting in increasingly seamless user interfaces which provide quick and easy access to a wide array of distracting content, from video games to social media and more. Pile on push notifications curated to keep users engaged with these apps, and many have found themselves deeply addicted to their smartphones. The experience of mindlessly swiping to and entering one's distracting app of choice by muscle memory alone before even realizing it has become extremely commonplace. With the advent of the smartphone, distraction accompanies you in your pocket, readily available at the swipe and tap of a screen [1], making it extremely difficult to maintain focus on more productive tasks.

Even those who realize the detriments of their smartphone usage habits have an extremely difficult time exercising self-control [2]. As a result, smartphone apps have been developed to help users combat their overuse habits with demonstrated effectiveness [3]. Research has also been conducted in the area, recommending different types of mobile apps and new intervention methods to both detect and combat mindless smartphone use [4]. At the core of many of these methods is the addition of some amount of friction to smartphone use to counteract the seamless nature of typical smartphone engagement. This friction can take the form of outright blocking distracting content [5], or of adding a delay between the automatic impulse to open an app and interaction with that app to promote mindfulness and awareness of behavior [3]. Others propose integrating small inconveniences or delays into the use of the application or smartphone itself to interrupt the mindless, distracted state [6]. Moreover, reflection of usage after distraction through methods such as screen time monitoring can promote mindfulness in regards to long term behaviors [7, 8].

In this paper, we propose a tangible and shape-changing alternative to these purely digital existing solutions in order to explore the potential of a physical intervention to interrupt mindless distraction in a novel manner during the use of a distracting app. While digital anti-distraction apps have proven effective within the bounds of the smartphone screen, we see potential in introducing alternate physical interventions to smartphone overuse. Through a shape-changing modality, we are able to alter the ergonomics of smartphone use, making it less comfortable to hold the phone and thereby distracting the user from distracting apps. This added physical inconvenience during engagement with an app nudges [9] the user to actively adjust their activity to the shape change, suggesting an exit from their default state of mindless distraction.

We present a proof-of-concept device named FocuShift (Figure 3.1a), which exhibits a shape-change in order to introduce an ergonomic intervention during meaningless [10] smartphone use. We conducted a 48-hour in-the-wild study in which participants' screen time was tracked for 24 hours with no device and for 24 hours with our device in order to probe the potential of our intervention in preventing smartphone overuse. Preliminary data suggests that our intervention has a significant effect on screen-time reduction and through interviews, we found that participants experienced heightened awareness of usage behaviors and redirected them towards more meaningful activities.

1.2 Thesis Aims

This thesis aims to build upon previous research exploring behavioral interventions against digital distraction by proposing a more physical modality of intervention. One of the challenges in this area is the balance between persuasiveness of an intervention and a user's willingness to adopt the intervention method. A system that fully blocks apps or continually pesters a user might be abandoned entirely due to frustration. On the other hand, digital intervention systems that preserve user agency can be overly gentle and easy to dismiss, allowing users to remain in their distracted state without much interruption. This work explores the persuasiveness of a shape-change intervention that alters the ergonomics of phone use as an alternative to purely digital methods, nudging users away from distraction while preserving the user's ability to make their own choices.

While the possibilities with shape-changing interfaces are endless, this thesis proposes one possible design for a shape-changing intervention device. Given its development as a phone-attached device, FocuShift's prototyping process was informed by several design criteria to maintain usability of the phone. Guided by insights from our user study, further design recommendations for future shape-changing intervention efforts will be highlighted.

To validate and gain further insights into our design probe, this thesis explores a field deployment of the FocuShift device. Promising initial data will be presented to corroborate the effectiveness of shape-change as an intervention modality. An emphasis will then be placed on the qualitative feedback received from participants to understand the nuances of the effects of FocuShift's intervention and to identify ways in which future shape-change interventions can be designed to fit more seamlessly into everyday smartphone usage while maintaining persuasiveness.

1.3 Thesis Contributions

This thesis offers the following contributions:

1) Proposes shape-change as a new avenue through which to provide behavioral interventions for digital distraction and presents one possible ergonomics-altering design for such an intervention device.

2) Verifies the efficacy of a shape-change intervention for smartphone overuse through field deployment and examines the implications and effects of using such an intervention by collecting qualitative feedback.

3) Identifies design recommendations for future work in tangible behavioral interventions for smartphone overuse.

CHAPTER 2

RELATED WORK

Researchers have explored multitudes of ways to both detect and intervene in digital distraction. While most of the research in this area explores digital interventions, some work has been done to develop more physical methods as well.

2.1 Smartphone Overuse and Ways to Combat it

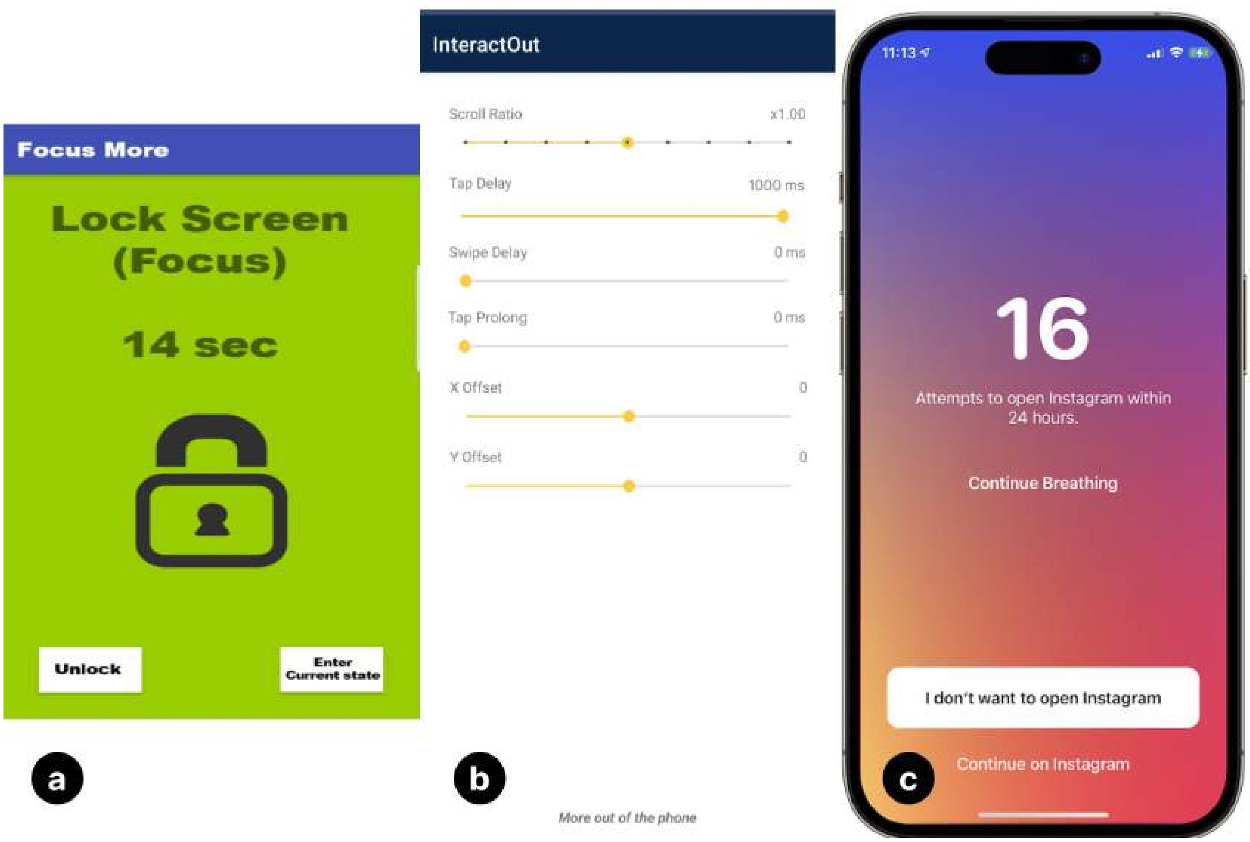

Figure 2.1: a) UI for *Exploring Context-aware Proactive Blocking for Distraction Management* paper's app, b) UI for *InteractOut*, c) Intervention screen for *OneSec*.

In the past few decades, all aspects of our life have been infused with smartphone use to an extent where users find it hard to put their smartphones down. In 2016, it was estimated that smartphones are tapped, swiped and clicked over 2600 times per day [1]. While this increased connectivity can be beneficial, phone use has been found to interfere with social activity [11], interrupt personal productivity [12] and heavily aid procrastination [13]. This rise of smartphone overuse is documented among a wide range of demographics [14, 15, 16]. As smartphones are now deeply embedded into all aspects of everyday life, making finer distinctions between what constitutes as meaningful or meaningless smartphone use is an ongoing research question. Now, more than ever, it is important to view digital wellbeing as a dynamic construct [17]. Lukoff et al. attempt to deeply probe this distinction using large-scale experience sampling [10]. Attempts have also been made to use data-driven classification methods to automatically detect problematic smartphone use even before it happens [4].

In order to combat this issue, many forms of solutions have been proposed, as exhibited in Figure 2.1. One-sec [3], is a popular app that introduces a small design friction [18] that forces a user to reconsider whether or not they intend to open that particular app or not. Lu et al. [6] explore interaction frictions to frustrate users while they are using a distracting app. Kim et al. [19] explore context-aware blocking where certain content is blocked based on the situational context that the user is in. For example, students would want to block social media access while they're in the library but maintain unfettered access when they're not. Lyngs et al. [2] provide a more detailed account of self-control in cyberspace centered around Dual-Systems Theory.

2.2 Tangibility Against Digital Distraction

While lots of digital solutions as described in the previous section have proven to be effective in various contexts, there remains a budding opportunity to explore solutions that *physically* add friction to try and prevent smartphone overuse. Researchers have also explored the use of tangible interventions to improve workplace well-being [20]. Sathya et al. [7] utilize the materiality of a receipt to try and improve screen-time reflection on YouTube.

Figure 2.2: a) *Morphees*, a self-actuating flexible attachment for the phone, b) *Bendi*, a shape-changing device for a tactile-visual phone conversation, c) *MobiLimb*, an anthropomorphic phone attachment for haptic feedback.

While the notion of using tangibility as an intervention for digital well-being is relatively new, we also build upon previous work, shown in Figure 2.2, that utilizes shape-changing devices on smartphones. Teyssier et al. [21] explore how "anthropomorphic devices bring new input and output capabilities to existing devices". Park et al. [22] propose a shape-changing device that explores the use of a shape-changing device for a 'tactile-visual' phone conversation. Pederson et al. [23] produced "51 videos of a shape-changing handheld device by systematically varying seven parameters of shape change" to study the nature of notifications in a hypothetical shape-changing phone. Roudaut et al. [24] explore the possibilities of "high-resolution shape change" using a self-actuated flexible mobile phone device. These rich explorations provide us a starting point to explore the use of shape-change as an intervention for digital well-being. In our preliminary work, using a shape-changing phone case, we explore the potential of using shape-change as an ergonomic intervention to prevent smartphone overuse. Using shape-change as a way to introduce an ergonomic intervention has been explored in the form of slow robots [25] that slowly change the position of a monitor in order to encourage users to constantly modify their sitting posture.

Supported by these previous works, our approach is centered around triggering a shape-change around the 10-minute mark [26] when a user is using a distracting app.

CHAPTER 3

FOCUSHIFT DESIGN PROBE

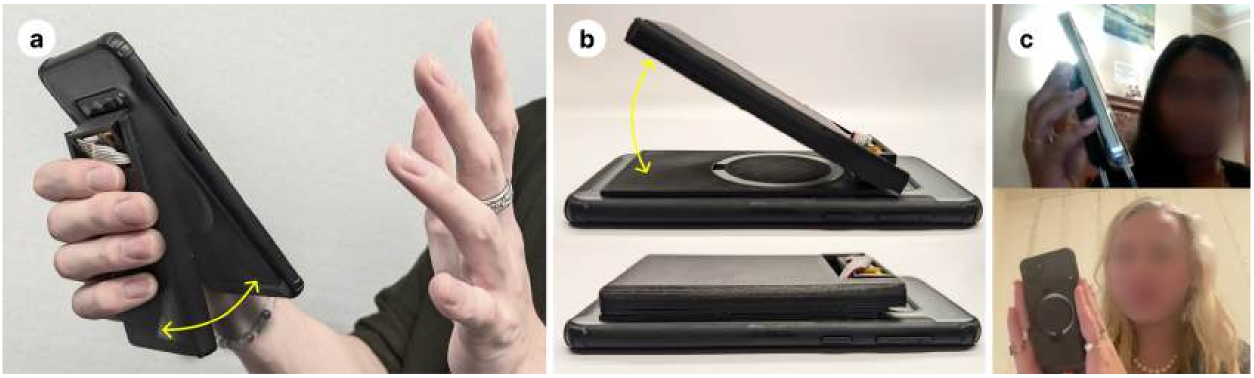

Figure 3.1: a) FocuShift device that changes its shape, aiming to intervene in smartphone overuse, b) Actuation of FocuShift device that was set to actuate 50 degrees for our study, c) Participants from the study holding the device to describe their experience.

While a real-world implementation of our device would require multiple rounds of refinement and testing in order to prepare it for long-term deployment, in order to test our idea, we constructed a design probe (Figure 3.2) to evaluate the potential of our intervention in-the-wild.

3.1 Rationale: Why Shape-Changing?

Our world is becoming increasingly digital. Photos which were once physical are now stored on smartphones and often shared on social media. The days of record players are long gone, with music streaming services making it possible to enjoy music with only an internet connection. This shift has brought with it many benefits. For one, cloud services have made digital mediums even more ubiquitous, making it possible to access images, songs, and more from any device anywhere in the world. But along with this digitalization of the world comes a forfeiting of what makes tangibility so meaningful.

Physical objects provide affordances through properties like shape, temperature, and texture, appealing directly to our senses. On the other hand, digital content can only be experienced and handled through "mediation," either from a screen or some separate controls [27] given its intangibility. Digital content is also transient in nature, with its ability to disappear and reappear at any time, whereas physical objects have permanence that can only be renounced through some form of destruction or displacement.

Though advantageous in many ways, the reproducibility of virtual possessions contributes to the feeling that they are less "real" than physical ones [28]. Meanwhile, the physical form and space taken by physical assets force people to continually assess what to keep and what to dispose of, leading to a greater sense of awareness of and reflection on physical belongings.

This transience and lack of perceived "realness" of digital mediums are properties that do not lend themselves well to applications that require a more imposing and powerful effect. Behavioral interventions work best when they are able to capture the user's attention and, in the case of digital distraction, "shock" the user back to reality. Transience implies the opposite for digital interventions—that they may be easy to dismiss or ignore. Therefore, it is worth exploring how reintroducing a bit of tangibility into our digital behaviors and management thereof might fare in this regard.

Tangibility in the form of shape-changing interfaces has been demonstrated through many works to enrich user experience in a myriad of ways. Shape displays have been utilized to represent data in a more enriching and intuitive format as well as provide new opportunities for interaction [29]. Self-actuated flexible attachments to smartphones have been explored as a way to provide convenient affordances that adapt to phone usage [24]. Shape-changing devices have also been developed to enhance virtual interactions and conversations between two people [22] or to provide haptic feedback that personifies the relationship between users and their phones and fosters curiosity and engagement [21].

It is clear that shape-change is a promising, tried-and-true paradigm through which new and enriching experiences can be created. FocuShift seeks to examine how this promise might apply to the behavioral intervention space through an ergonomics-focused shape change aimed at disrupting distracting smartphone behaviors. Successfully addressing the transience and lack of physical realness of a virtual format and harnessing the power of shape change, FocuShift is designed to ascertain in what ways the experience of a behavioral intervention can be enriched when it takes place in the physical rather than the digital world.

3.2 Design Criteria

FocuShift's hardware development and prototyping process was informed by several design criteria important for seamless use with smartphones.

1) **Size.** Given that FocuShift is designed as an attachment to the back of the smartphone, it needed to be as thin as possible to ensure that phones would still be easy to use and carry around, whether in-hand or in-pocket, with the device attached. For similar reasons, it was required to fit within the length and width of the typical smartphone.

2) **Torque.** The intervention needed to be significant enough to draw the user's attention away from distracting phone usage and strong enough so as to not be easily resisted. As a result, the motor used to actuate the device needed to provide enough torque to actively alter the ergonomics of phone use and move the phone in the user's hand.

3) **Portability.** The device needed to be suitable for everyday smartphone use. As such, it needed to be entirely wireless with all components contained within the device itself so that phones could still be carried around and used throughout the day.

4) **Power Consumption.** Smartphones are typically carried by users wherever they go throughout the day and are thus designed to last an entire day on one charge with normal use. For maximal convenience, the FocuShift device needed to match this charging frequency of once per day so that users could charge it alongside their phones. Therefore, the device needed to have low idle power consumption and a battery with enough capacity to last an entire day on a full charge. This informed the choice

of microcontroller. Balancing battery capacity and size was one of the challenges of hardware design.

3.3 Hardware

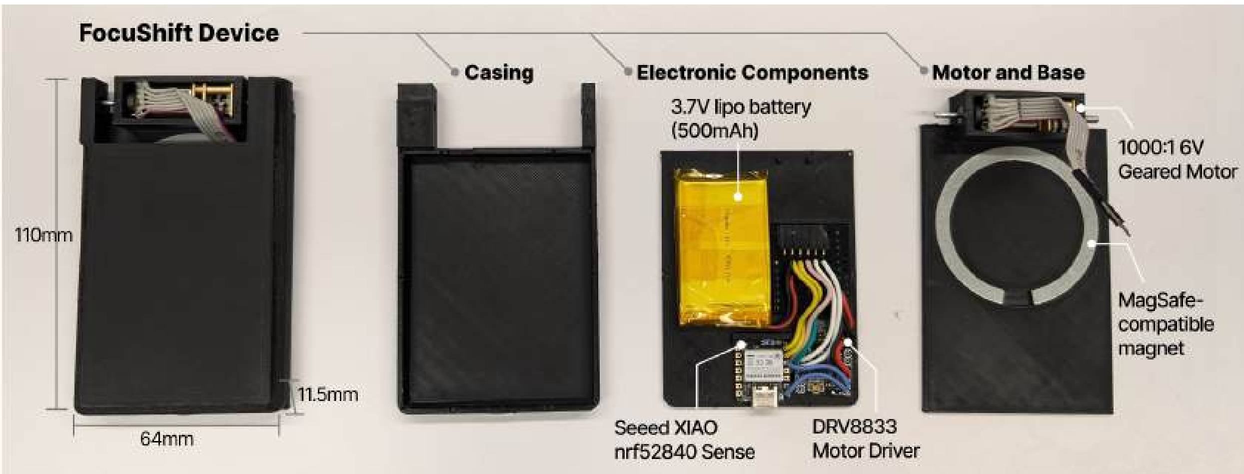

Figure 3.2: FocuShift device dimensions, and internal components.

As shown in Figure 3.1a and b, our device is designed to be attached to a phone case using a MagSafe [30] connector. While MagSafe is primarily used by Apple devices, third-party cases exist to use a MagSafe connector on Android devices. The MagSafe connector allows us to easily attach our hardware to a phone case. In turn, this allows us to recruit participants with a wide variety of phones. Due to the ease of development, we stuck to the Android ecosystem for the purpose of this inquiry.

Figure 3.2 shows the internal components. We use a Seed Studio XIAO NRF52840 Sense [31] as the main micro-controller along with a DRV8833 Dual-Channel H-Bridge to control a single N20 Micro-Metal Gear Motor from Pololu (1000:1), driven by a 3.7V LiPo battery (500 mAh) stepped-up through a 7.5V U3V16F7 Voltage Regulator modulated to output 6.1V. The motor was selected after a series of preliminary experiments to identify the amount of torque required to generate enough shape-change that will nudge the user to put their phone away. We rely on a simple mechanism to generate the shape-change in order to maintain robustness in-the-wild. All parts are 3D printed using PETG, prioritizing durability. The entire circuit is built on a custom protoboard and is fully enclosed within the case attachment.

3.4 Hardware Prototyping Process

This section details the iterative process of building the FocuShift device.

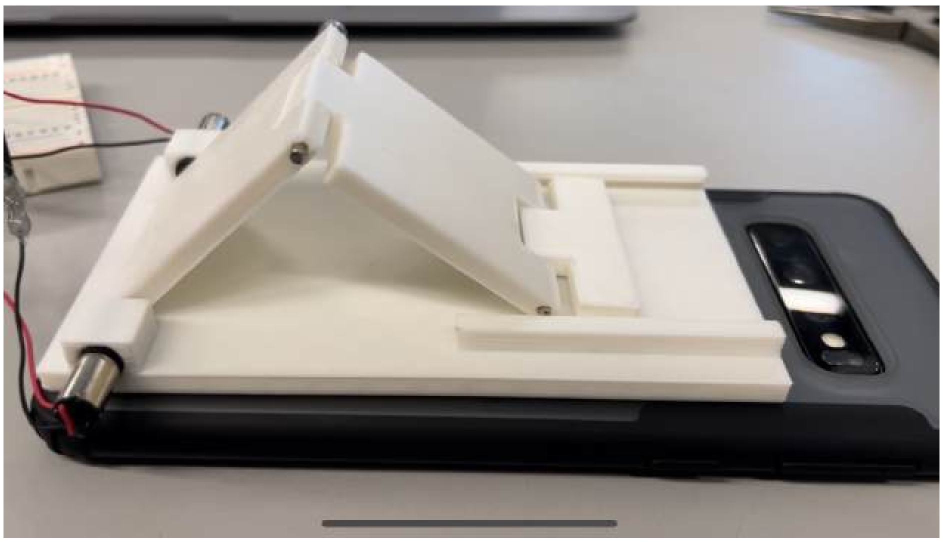

Figure 3.3: First prototype of FocuShift. Two micro DC motors expand and retract the printed mechanism on the back of a smartphone.

The first design, show in Figure 3.3, for FocuShift focused on minimizing the thickness of the device by utilizing two micro DC gear motors to expand a hinged 3D-printed mechanism. Even two of these motors together could not provide enough torque to provide any meaningful movement under the weight of the phone. This thin design—4mm in total thickness in almost all places—also called into question where the components of the device would be stored. As such, we opted to explore thicker designs and larger motors.

Early in the prototyping process, metal servo motors were also experimented with (Figure 3.4) given their higher gear ratios and built-in positional control. While the servo was able to provide more torque than the two micro DC motors, the shape-change was still easy to

Figure 3.4: Second early prototype of FocuShift. A metal servo motor actuated the flap.

resist and insufficient to lift the smartphone out of one's hand. The large size of the servo motor itself was also a limitation, forcing the "flap" to be very narrow and unnecessarily thick, which was not ideal for providing a meaningful ergonomic effect.

Ultimately, 6V Polulu micro-metal gearmotors were decided upon as a larger and more powerful motor. After experimenting with the 380:1 gear ratio version and not observing enough torque, the 1000:1 gear ratio version was settled upon. This gearmotor provided enough torque to lift the phone out of one's hand, as desired, and was small enough to allow for a fairly thin design for the device. Early versions of the device were powered through a breadboard and thus featured a thinner flap. In the final version of the device, the flap was made thicker to house all of the electrical components, with the added benefit of being more robust to physical stress from the motor. The thickness of the final design probe device is still not ideal, making the use of thinner batteries and components that are able to provide the same functionality an important future work.

3.5 Software

In order to communication between our device and the smartphone, we developed a custom Android app using Kotlin. Our app communicates with the Seeed Studio XIAO over BLE to trigger the shape change. The shape-change is detected by reading 'overuse' notifications from an app usage tracker [32] that we asked participants to install from the Google Play Store.

The app includes options to turn the shape-change on/off to switch between study conditions (Section 4.1.1). The user designates distracting apps on the app usage tracker. The usage tracker sends notifications every minute after opening a distracting app. The shape-change is triggered after the first minute of usage in each distracting app and every ten minutes afterward. Each movement of the device is defined as one opening of the "flap" (shell and components) at a 50° angle and one closing of the flap back to the 0° position. Each intervention is defined as 10 of these movements.

CHAPTER 4

FIELD DEPLOYMENT

We designed a within-subjects field deployment for 48 hours to test our design probe. We recruited 8 participants (avg. age: 23.875, 5 Female, 3 Male) through local channels and filtered participants to only those who had compatible Android smartphones. Our study was approved by our University's Institutional Review Board (IRB24-1283).

4.1 Study Design

The study aimed to address two primary questions: (1) Does the mere presence of the bulky case impact distracting app usage? and (2) Does the shape-change influence distracting app usage? Given the bulky nature of the device, we hypothesize that overall phone usage would naturally decrease due to the less comfortable ergonomics. Beyond this, we seek to determine whether the shape-change itself has a significant role in curbing distracting app usage. If the shape-change proves to be impactful, it opens up the potential for future, more streamlined designs that seamlessly integrate with the phone's form factor. These designs could specifically target distracting app usage without affecting regular, productive interactions.

4.1.1 Study Procedures

Once participants were recruited, they underwent an onboarding session where we set up the device, demonstrated the app's functionality, and asked them to complete the Smartphone Addiction Scale – Short Version (SAS-SV) questionnaire [33]. Each participant experienced two conditions over 24-hour periods: (A) the case installed without shape-change (3D-printed block), and (B) the case installed with shape-change (device). Both the 3D-printed block and the device were of the same thickness. The order of these conditions was counterbalanced

Table 4.1: Participant summary showing the distracting apps picked by each participant along with their SAS-SV score and their study order.

Participant ID	Chosen Distracting Apps	SAS-SV Score	Study Order
P1	Instagram, Facebook, Reddit	22	No Shape Change → Shape Change
P2	Reddit, Instagram, Twitter	39	Shape Change → No Shape Change
P3	Instagram, Facebook, Amazon	27	Shape Change → No Shape Change
P4	Instagram, Youtube	37	Shape Change → No Shape Change
P5	YouTube, FaceBook, Internet Browser	44	Shape Change → No Shape Change
P6	Internet Browser, Messages, WhatsApp	34	No Shape Change → Shape Change
P7	Internet Browswer, Gallery, WhatsApp	40	No Shape Change → Shape Change
P8	Internet Browser, WhatsApp	43	No Shape Change → Shape Change

across our eight subjects to mitigate order effects.

We utilize a pre-existing app usage tracker [32] to provide historical app usage data for 15 days and also during the study, giving us a neutral baseline period in which the design probe was not yet installed on participants' phones. Since this baseline data was gathered pre-recruitment, it is free from any potential observation effects.

At the end of each 24-hour period, participants completed a questionnaire specific to the condition they had just experienced. After the full 48-hour testing period, participants took part in a ∼60-minute interview where we discussed their questionnaire responses and explored their overall experience through open-ended questions.

4.2 Results

In this section, we discuss the results of our study. We collected a wide range of data to try and understand the effectiveness of our design probe.

4.2.1 Preliminary Quantitative Data Analysis

Although our user study is limited in terms of the number of participants and the duration of the study, the results are extremely promising. While the results suggest that the mere existence of the bulky phone case had a negative effect on screen-time, shape-change had a significant effect on screen-time and distracting app usage. As shown in Figure 4.2 (top), there was a 39.7% drop in distracting app usage. On average, this represents a 56 minute drop in screen-time across participants. Detailed results across apps are shown in Figure 4.2.

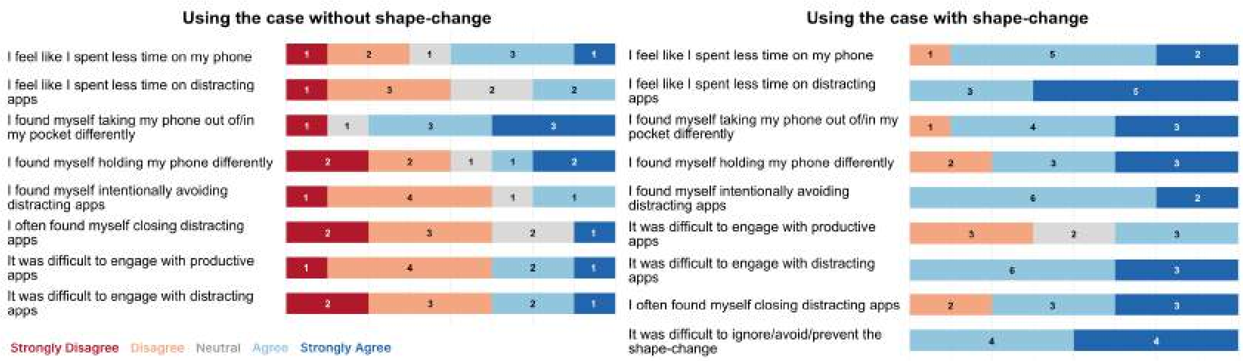

Figure 4.1: Questionnaire responses

4.2.2 Questionnaire Results

The results of the questionnaire (Figure 4.1) suggest that the shape-change condition was considerably more effective than the non shape-change condition. In the shape-change condition, all participants either agreed or strongly agreed that the shape-change made it difficult to engage with distracting apps. Participants in general had more negative feelings towards the non shape-change condition. The nuances of these results and the possible explanations behind them are discussed in the next section.

4.3 Interview Results

In this section, we present several key themes that emerged during the interviews:

Heightening Awareness of Phone Usage Behaviors. Every participant noted that the shape change intervention from the device increased their awareness of their phone usage as well as the amount of time spent on their phones. For instance, given that the intervention is triggered 1 minute after opening a distracting app, many participants mentioned being much more vigilant of the time spent on a distracting app, aiming to complete their activity on the app before the shape change triggered so as to avoid the "annoying" nature of the intervention. According to P4, *"Whenever I was using the phone, I had in the back of my mind, the time limit of [one] minute. Otherwise, it will [shape change again]."* Others noted that the device's movement brought them "back to reality," with P2 recalling that *"sometimes it'd turn on and... I'd be like why am I even here I'm not that interested in [this app]."* When venturing past the 1 minute park and triggering the intervention at 10 minute intervals, P5 claimed that *"the final time it went off, I was like, okay, so I have been on this app for 40 minutes. Maybe I should take a break."*

Form Factor and Ergonomics. Several participants noted form factor as a very noticeable quality of the device. Some noted that it was difficult to place the device in their pockets given the thickness of the device, and some even chose to simply carry their phones in their hands or in their bags instead. As stated by P8, because of the thickness, *"when I try to put it in my pocket, I have to be really careful, and then when taking it out I have to be careful again."* From one perspective, then, we see the thickness of the device augmenting the user's awareness of their phone usage behavior by creating a state of mindfulness when handling one's phone. On the other hand, this somewhat bulkier form factor presented some inconveniences for those who were accustomed to keeping their phones close on their person. However, this experience was not universal, as some were for the most part unaffected by the thickness of the device on their phone. P1 said *"I didn't really change the way that I was holding the phone much during the time that I had it,"* noting that the added device happened to feel normal to her. Furthermore, P7 provided justification for her lack of reaction to the device's thickness, noting that *"since I use a magnetic battery pack often to charge my phone," "I'm super used to this, so holding is not a big deal."*
The added thickness of the device also presented a change to the ergonomics of smartphone use for some participants. P3 shared that it was *"kind of awkward to scroll"* with the added thickness, even with the passive block, given a newfound inability to reach the opposing side

of her phone with her thumb. While watching YouTube for an extended period of time, P5 recalled *"my wrist would get tired"* after 40 minutes of holding the phone in an awkward position to avoid being disrupted by the shape change of the device. P5 noted this feeling of discomfort in the wrist as a contributor to his decisions to stop watching YouTube.

In many cases, participants chose to hold the phone in a different way in order to minimize disruption from the shape-change intervention. We asked each participant to demonstrate ways in which the shape change altered their way of holding the device (Figure 4.3). Some held their phones in a different spot with one hand while some tended toward holding their phones tenderly with both hands to avoid the shape change. P1 didn't alter her hand position at all, while P7 chose not to hold her phone at all while the shape change was happening.

Social Factors. When asked what about the shape changing intervention prompted them to avoid using distracting apps on their phones, several participants pointed to potential awkward situations when in public or around other people. Some felt that having the device moving and the motor whirring while around other people would be embarrassing, while others simply sought to avoid the added inconvenience of having to explain the device to people each and every time. According to P1, if caught in public with a shape changing device, *"I have to explain, oh, I'm doing this experiment from school"* and *"I don't want to have to deal with that."* Similarly, P7 explained *"you might be in a public space,"* like a library, *"and then your phone starts moving and making noise and people start watching you."* Citing her personal experience in the matter, P2 shared that *"I didn't want it to move...while I was on the train, so I just listened to music,"* indicating that her behavior shifted toward a less distracting activity due to the social pressures of being in public with the device.

Redirection to More Productive Devices or Tasks. When the user puts their phone down due to the shape changing intervention, the next natural question is *"what did you do with your time afterwards?"* Interestingly enough, for some participants, the shape change redirected participants toward healthier practices to fill their time and meet their distraction needs when remaining on their phones became less appealing. P1 revealed that *"I normally browse Facebook or social media during lunchtime. But then now that I'm aware that that is going to trigger the shape changing, instead of browsing social media on my phone, I switch to reading the news."* Similarly, P7 shared *"I usually like to read articles off my phone, but [with the device] I cannot do that. So I just read books instead." "To recharge my dopamine."* Others mentioned switching to more productive tasks like work on different devices. P3 noted, *"I would definitely just like use [my phone] less and instead just do something else, like go work on my laptop."* When asked about her behavior once the shape change was triggered, P8 replied *"I'll just put it away or I'll just get out of the app,"* because *"it starts moving and you're like, wait, I have better things to do anyway."*

Redirection to Unproductive Tasks on Other Devices. When one source of distraction is removed, it might feel natural to shift one's attention toward an alternative. Some participants did just that. P1 reluctantly divulged, *"I shifted my usage of the distracting apps,"* like Reddit, *"to my computer."* While this might be seen as a failure of the FocuShift device to remedy distraction, P1 also noted that her laptop is a device with fewer distracting apps on it, on which it is easier to avoid falling into a prolonged cycle of distraction than on her smartphone. P2 *"watched a movie."* To her, watching movies is a more fulfilling distraction than scrolling on social media on her phone.

A Notification vs. A Deterrent. Several participants felt that 10 movements per intervention took too long given that they had to wait for the device to stop moving. Bringing some nuance to this conversation, P5, who spent a prolonged period of time on YouTube with the device shape changing against his best wishes, made an interesting distinction about the movement pattern of the device. If the intention is to utilize the shape change intervention as an awareness-cultivating notification about how much time has been spent on a distraction app (10, 20, 30 minutes), then 10 movements *"was a bit long,"* and the point can be conveyed within 3-5 movements. *"But at the same time to serve the purpose of it being annoying and forcing you to stop the app, I think it was perfect. If you're on YouTube and you're trying to watch the video, but it keeps going, it just makes it hard to watch the video."*

Annoying During Productive Tasks on Distracting Apps. Some participants shared a desire for the intervention to be capable of distinguishing between productive and unproductive tasks within an app designated as distracting. P1 claimed the device was *"particularly bothersome... last night when I was not using Reddit because I was procrastinating"* but rather searching for information. According to P2, *"there's not a sharp line between productive Instagram usage [like messaging friends and family] and non-productive Instagram usage [like scrolling on Instagram reels]."*

Impacting Usage without Moving. In many cases, participants recalled avoiding phone usage without the need for the device to actively shape-change. The idea that the device would change shape and be *"annoying"* was enough to deter them from opening distracting apps. P3 would *"consciously just avoid one minute or if I did go to apps, it would be just really quickly"* in order to avoid triggering the shape change in the first place. P2 started *"to pick it up less because it was just kind of going to be a hassle."*

Unintended Intervention Effects (Failing Successfully). Throughout the course of their 24 hours with the device some participants noticed unintended features of the device that nonetheless provided the intended effects of prompting participants to reduce screen time. P3, like all other participants, avoided resisting or combating the shape change out of concern for the integrity of the device and its motor, explaining that *"I would not squish it because I didn't want to break the machine. So I would just move my hands away from it."* P8 pointed to the effect that the thickness of the device had on her smartphone usage behavior, claiming *"I guess, I found myself reaching for my phone a little less often. Because it's bulkier."* P2 was also concerned about the appearance of the device, sharing that *"I'm not as interested [because] it made my phone less attractive"* and aesthetically appealing.

Comparisons to Digital Methods. An easy comparison to make is one between FocuShift's shape-changing intervention and a common digital screen time intervention on a smartphone. Several participants claimed that digital interventions are much easier to ignore and dismiss than the shape-change intervention, which they described to be more annoying. According to P4, *"I think the digital thing doesn't work for me. I just closed the app and then kept on using it again. But here it was really restricting me, like physically you can't use it."* P5 had even stronger opinions, claiming that with a digital screen time notification, *"I never once was like, oh, let me just stop using it. It doesn't work for me. But with the shape change, it does the shape change. Yeah, maybe I should stop because it's annoying."*

How to Make the Device Usable in the Real World. Some participants had interesting things to say about what might be needed for them to consider using the device in their everyday lives. Given her concern with the aesthetics of the device, P2 shared that if it was sleeker and quieter and matched her phone color, *"then I can characterize it as a cute and silly... little creature [that tells me] hey get off your phone please."* From a more practical standpoint, P5, who spent what he saw as too much time on YouTube, expressed his desire for the device to *"be more aggressive just for my personal sake"* so that it *"forces me to stop using the device."* He went on to say that if *"it gets progressively worse the more you [stay on a distracting app], I think that would be a game changer. I think that would be something that I would take significantly longer to get used to."*

Potential Long Term Effects of a Shape-Changing Intervention. Participants were generally optimistic about the potential for a shape-changing smartphone overuse intervention to improve their relationships with their smartphones over the long term. For one, participants imagined shape-changing interventions redirecting them toward healthier habits. P4 conjectured *"I think in the long term, my contact with the phone would definitely decrease and I would be doing more productive stuff, either on other [more productive] digital sources or just playing sports and remaining physically fit."* Instead envisioning her long-term relationship with a shape-changing intervention within the context of her relationships with others, P7 claimed that social pressure would be effective at altering her behavior. She explained, *"If people know that I am trying not to use my phone, when I'm with them, I will try not to use my phone [as a result] because they are expecting me not to."*

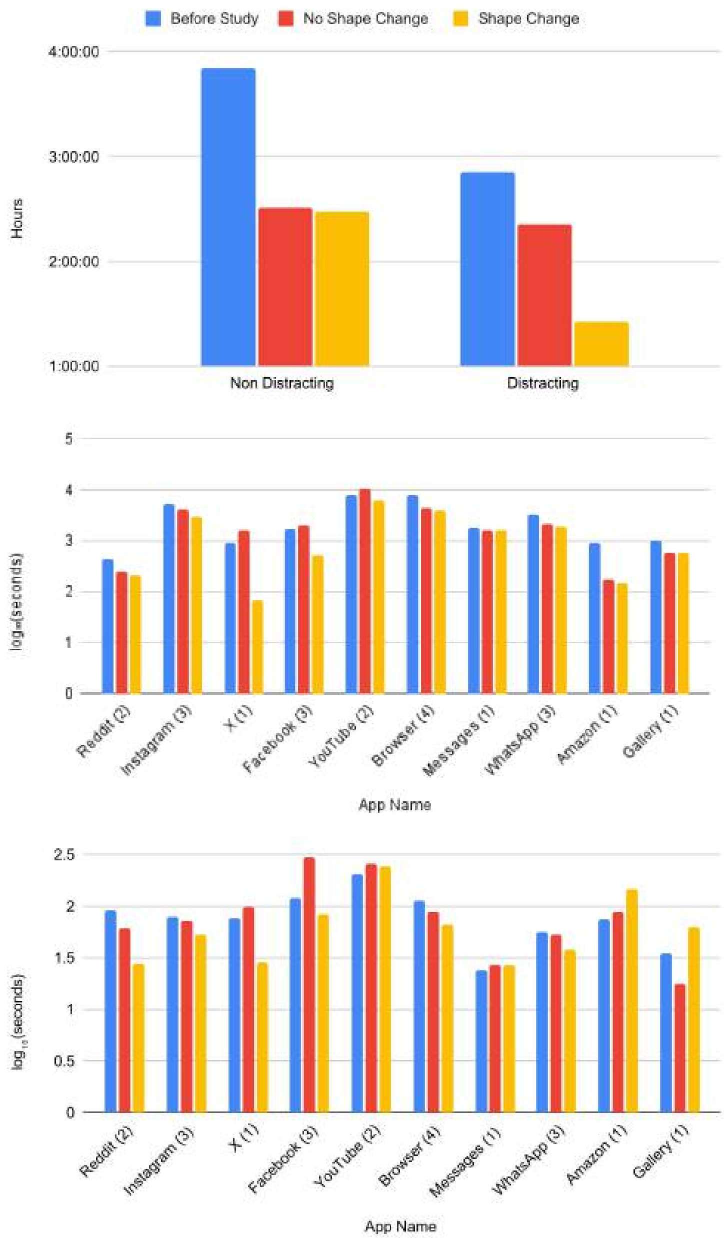

Figure 4.2: Quantitative data from the study. Top - Average screen-time across all participants. Middle - Average Screen-time per app across participants. Bottom - Average Duration Per App Use Across Participants. In the parentheses next to the app names is the number of participants who designated the app as distracting.

Figure 4.3: Participants showing how they held the phone when the device actuated. It revealed that they held in different hold types, including 'single-hand avoid HOLD (P3, P5, P8)' 'double-hands avoid HOLD (P2, P4, P6),' 'Keep Holding the Same (P1)' 'Place on a table (P7).'

CHAPTER 5

DISCUSSION AND FUTURE WORK

In this section, we discuss the implications of our learnings and the limitations of our work.

5.1 Different Forms of Shape-Change

In this inquiry, we limit our intervention to a simple shape-change designed to minimize complications during in-the-wild testing. However, exploring more complex shape-change mechanisms at different resolutions, as seen in [24], could yield more nuanced outcomes. For instance, participants could be provided with fine-grained control over the resolution of the shape-change, allowing for more personalized experiences. The relationship between ergonomic conditions and user behavior may also evolve—users might associate certain levels of discomfort with less meaningful usage and, conversely, attach better ergonomics to more meaningful interactions. The finer details of shape-change could have intriguing effects, such as the implementation of micro-textural changes that subtly alter the device without drastically affecting its overall form. These could lead to more socially acceptable interventions, where the changes are less conspicuous to bystanders.

5.1.1 Macro vs. Micro Shape Change

One possible direction would be to explore the differences between larger shape-changing feedback (macro shape change) and smaller shape changes (micro shape change). By nature, larger movements and moving parts like those used by FocuShift lend themselves to a more ergonomic-focused intervention. These macro shape changes inherently affect the size or shape of the smartphone during use. On the other hand, micro shape changes might naturally provide more haptic feedback. Rather than altering the way in which the phone has to be held, smaller moving parts have the potential to impart textural changes to the user, for example by poking or prodding the hand. An instance of this is shown in Figure 5.1, where small spikes protrude and retract when a user enters a distracting app, providing a somewhat uncomfortable haptic experience rather than forcing the user to hold the phone in a different manner.

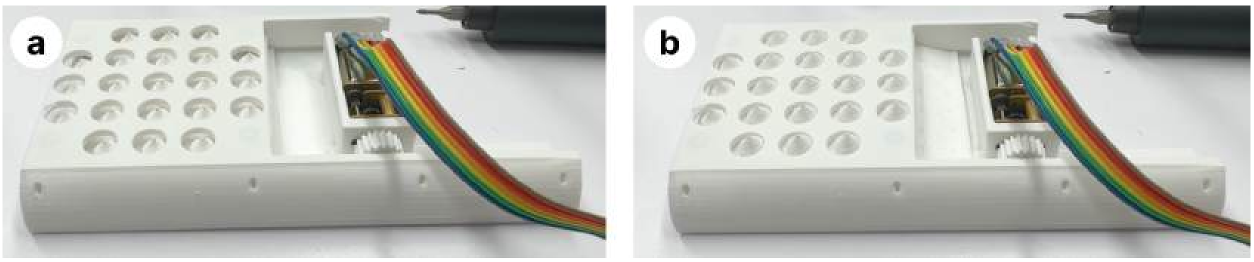

Figure 5.1: A prototype with moving spikes initially built to explore the differences between macro and micro shape change for smartphone overuse intervention. The spikes are designed to poke the user's palm while holding a smartphone. a) Spikes Retracted, b) Spikes Protruding. *(Designed and built by Jaden Hamilton).*

5.1.2 Macro Example: Pneumatics

Significant work has been done exploring pneumatics in shape-changing actuation. A pneumatic pump can inject compressed air into flexible materials to make them expand and contract. Cui et al. employ pneumatic actuation to inflate cells within a lattice structure (Figure 5.2) for dynamic and robotic applications [34]. While an employment of pneumatic actuation for a smartphone intervention would be decidedly less complex, an inflatable structure attached to the smartphone that can be dynamically inflated and deflated to alter the shape and size of the phone can be effective in creating more complex ergonomic experiences for distracted users. The current technology may not allow for a convenient application of pnuematics as pneumatic pumps are often large and noisy, but it is worth exploring the different types of ergonomics-altering shape change that can be achieved with this method.

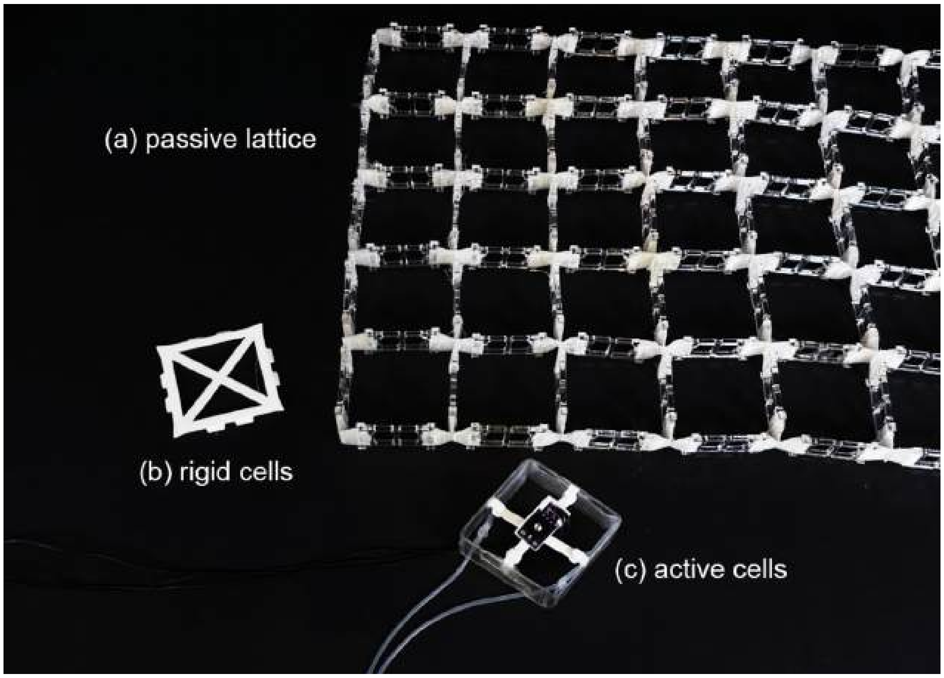

Figure 5.2: *Robotic Metamaterials*, a shape-changing device capable of robotic function that uses pneumatic actuation.

5.1.3 Micro Example: Shape Display

Shape displays have a demonstrated ability to communicate information in an intuitive, enriching, and tangible manner and to provide fine-grained feedback and shape generation. Indeed, they have seen use in smartphones already; Jang et al. integrated a small pin array (Figure 5.3) into the edge of a smartphone case for haptic and tactile interaction [35]. A miniature version of a shape display integrated into a smartphone case may be able to provide more varied interventions, making different types of feedback for different situations, positive or negative, possible.

5.1.4 Micro Example: Electroosmotic Pumps

Recent work has explored electroosmotic pumps (EOPs) as compact shape change actuators that use electricity to influence the flow of fluids through flexible materials. These actuators are reminiscent of pneumatic actuators, but without the need for bulky hardware. Yu et al.

Figure 5.3: *Haptic Edge Display*, a smartphone case containing an actuated pin array for haptic and tactile interaction.

use EOPs to create different shape-changing displays (Figure 5.4) with glass fiber filter as a membrane and propylene carbonate as a pumping fluid [36]. The compact nature of these shape displays make them suitable for everyday use with smartphones. EOPs may also allow the design of different types of micro shape change interventions for different situations.

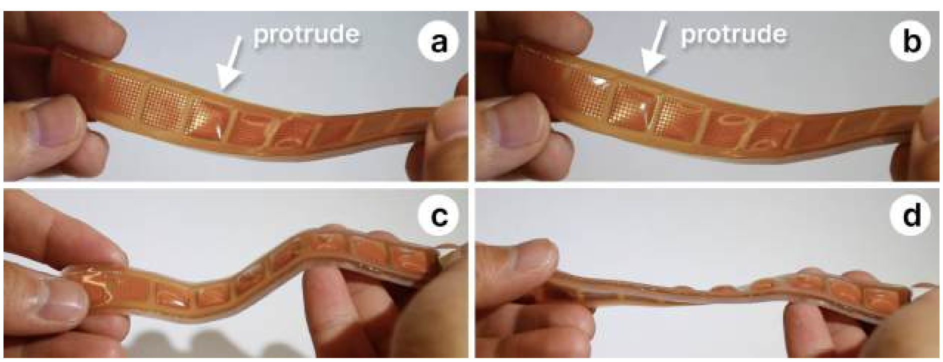

Figure 5.4: A strip shape display proposed as part of *FlexEOP*, a method for creating flexible shape displays using electroosmotic pumps.

5.2 More Robust Baseline Comparisons

5.2.1 Pure Haptics

In addition, while we establish two baselines in our study (pre-study and without shape-change), we do not delve into the potential of purely haptic feedback, such as vibration or electro-tactile stimulation. Although ergonomic interventions hold promise, subtler forms of feedback may be explored for their potential to offer more discreet and less intrusive implementations. This opens up possibilities for less bulky interventions that still provide meaningful user experiences.

A major question that may be raised with shape-changing interfaces is how shape-change compares in its effectiveness as an intervention to these less complex forms of haptic feedback. Therefore, it may be worth testing purely haptic feedback as a baseline comparison to shape-changing feedback in its effectiveness in a smartphone overuse intervention.

5.2.2 Other Disruptions

In a similar vein, other non-haptic forms of intervention can be explored as baselines. Something as simple as sound may also have a disruptive effect suitable as an intervention. Purely digital interventions would also be important to test against, given that most intervention systems against digital distraction are themselves digital.

5.3 Customized or Adaptive Shape-Changing Intervention

To examine the merits of shape-change as an intervention modality, the mechanism of the intervention itself was deliberately kept simple and consistent to minimize confounding factors. Each participant experienced the same intervention at the same frequency using the same trigger event. This proof of concept design probe thus opens the door for the development of a more robust and feature-rich intervention system that employs a shape change.

For instance, several user study participants expressed a desire for an ability to customize the time intervals between interventions, the number of shape changes per intervention, and the speed or urgency of each intervention, among other parameters. One possibility would be to make shape-change interventions more frequent and urgent the longer the user remains on a distracting app.

As another example, just in time adaptive interventions have also been explored recently and applied to the realm of digital distraction [37]. These systems use machine learning models with different features to predict when a user is engaging in overuse and decide when to deploy an intervention. Users are also kept in the loop, providing feedback that updates the model and adapts the intervention to the user's behavior. It may be worth inquiring into whether combining shape change with an intelligent intervention system like this would prove more effective than the digital intervention alone.

5.4 Long-term User Study

Our aim with this inquiry was to create a design probe to conduct a preliminary evaluation of our concept. For a long-term user study, however, the hardware would need to be streamlined, offering seamless charging solutions — or eliminating the need to charge altogether — and ensuring robust mechanisms that prevent device failure. Over time, participant perceptions may shift as they become more accustomed to the device, with comfort and usability playing a significant role. Additionally, participants may develop their own ergonomic adaptations to accommodate the device, even in the face of its shape-changing features. These aspects require in-depth investigation through a long-term intervention to fully understand the user experience and the potential for sustained engagement.

5.5 Addressing Social Factors

While digital interventions tend to be private by nature, tangible hardware interventions often act as conversation catalysts, drawing attention from bystanders. In some cases, especially when the bystander grasps the function or purpose of the device, these interactions can provoke curiosity but may also invite judgment. The challenge in designing and implementing discreet, tangible interventions lies in balancing functionality with subtlety. As such, further exploration is necessary to understand the social dynamics and boundaries surrounding these devices, particularly in public or semi-public spaces, where their presence might influence social interactions or perceptions.

CHAPTER 6
CONCLUSION

This thesis proposes shape change as an unexplored modality for behavioral intervention against smartphone overuse. FocuShift uses a shape change that alters the ergonomics of smartphone use when a user enters a distracting app to disrupt the user's distracted state and foster greater awareness of smartphone usage behaviors. The design of FocuShift is informed by the need for the device to be integrated seamlessly into everyday smartphone use while the intervention is not active. The device features a BLE-equipped microcontroller that allows the FocuShift app to trigger the shape change one minute after opening a distracting app and every ten minutes afterward while the user remains on the app. A gearmotor with enough torque to pick the phone up off of the user's hand to alter the experience of holding the phone is used to create the shape change.

A 48 hour user study was conducted to explore the effectiveness of the FocuShift design probe in the wild, as well as to collect feedback and qualitative data on the effects of using the FocuShift device. Though a longer-term study would be required to concretely evaluate the efficacy of the shape-change intervention in mitigating smartphone overuse, the data compiled is promising and suggests that the intervention succeeds in reducing screen time, particularly on distracting apps. A questionnaire suggests that participants found FocuShift's intervention forcing them to adjust the way they handled their phones, making distracting app usage more difficult to engage in, when compared to a baseline. Interview results indicate that FocuShift successfully augmented participants' awareness of their phone usage habits and redirected participants away from distracting app usage on their phones. Participants also raise several opportunities for improvement and shed light on inherent differences between a digital and a tangible or shape-changing intervention.

These results inform what future work in the space of shape-changing behavioral interventions might look like. Such devices should consider the tradeoff between providing an intervention that is cumbersome enough to influence user behavior and the preventing the attraction of unwanted attention to the user while in public. A successful shape-change intervention should also be customizable or adaptive, making the intervention more catered to each individual's smartphone habits. FocuShift's shape change also presents just one possible form of actuation. Different types of shape change changes, both large and small, should be explored and compared to arrive at a shape-change intervention most optimal for smartphone overuse prevention. Finally, a longer-term user study is necessary to fully understand the effects of a shape-change intervention on smartphone overuse as well as how shape-change interventions compare to their much more widely-accepted digital counterparts.

Tangible and shape-changing interventions may hold the potential to provide more varied feedback for different scenarios as well as to provide a more physically compelling message. This potential is very much worth exploring further.

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