Decorative, Evocative, and Uncanny: Reactions on Ambient-to-Disruptive Health Notifications via Plant-Mimicking Shape-Changing Interfaces

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Figure 1: One of our artifacts used in the study, with the ability to move its stems up and down at a variety of speeds. Various scripted movements using this mechanism were presented to interviewees to capture their impressions on ambient-to-disruptive notifications using Shape-Changing Interfaces. Please see our supplemental video for animated examples of all movement types used in our study.

ABSTRACT

Ambient Information Systems (AIS) have shown some success when used as a notification towards users' health-related activities. But in the actual busy lives of users, ambient notifications might be forgotten or even missed, nullifying the original notification. Could a system use multiple levels of noticeability to ensure its message is received, and how could this concept be effectively portrayed? To examine these questions, we took a Research through Design approach and created plant-mimicking Shape-Changing Interface (S-CI) artifacts, then conducted interviews with 10 participants who currently used a reminder system for health-related activities. We report findings on acceptable scenarios to disrupting people for health-related activities, and participants' reactions to our design choices, including how using naturalistic aesthetics led to interpretations of the uncanny and morose, and which ways system physicality affected imagined uses. We offer design suggestions in health-related notification systems and S-CIs, and discuss future work in ambient-to-disruptive technology.

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CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Ubiquitous and mobile computing systems and tools**; *Participatory design*; • **Hardware** → **Emerging interfaces**.

KEYWORDS

Shape-Changing Interface, Ambient Information System, Self-Tracking, Notification, Personal Data, Research through Design, Human-Plant Interaction.

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1 INTRODUCTION

The health of the human body usually responds best to a balanced and consistent schedule. Sleep irregularity is linked to adolescent dysfunction, cardiometabolic diseases, and many other negative health factors [1, 46]. Metabolic health is affected when sedentary time is not regularly broken up by activity [57]. Regular liquid intake is important, as only a few hours of reduced hydration can result in body water deficits [13]. Many medications are prescribed to be taken on a daily timetable to maintain proper concentrations in the body. However, people are surrounded by distractions and often preoccupied with life demands, finding it difficult to maintain a regular schedule for their health.

In response, several applications exist that attempt to remind people to perform an activity in a recurring manner for their health. For example, Fitbit allows people to set hourly reminders to encourage reaching step count sub-goals (e.g., move at least 250 steps every hour) throughout the day. Many medication reminder apps also use a time-based reminder when it is time to take a new dose [70]. However, because health-related events are important but generally not critical immediately, people may temporarily de-prioritize such activities. Thus, the time-based reminder falters if the user is not in a state to perform the requested action immediately. The same preoccupations that make it difficult for people to maintain their own schedule also thwart reacting to such alerts; someone receiving a Fitbit notification while recording themselves for a lecture would generally not wish to start pacing around the room to reach their step goals. Even if the user is allowed to snooze the notification, this still demands immediate attention and a specific action, which may not be possible for someone deep in the middle of a task.

Another deficient scenario would be if the user fails to notice the notification. People are already bombarded with notifications emanating from their devices [42, 60], vying for the same amount of attention from the user, regardless of their true priority. A user may misinterpret a health-oriented notification for another that does not need immediate attention, and the reminder is soon lost. Or, another action might coincidentally draw a person away from their device just as the notification arrives. Merely increasing the number of alerts to ensure acknowledgement would not be a suitable solution, as fatigue may set in from the overuse of notifications, upsetting people to the point of terminating the use of the system [55]. To support users wanting to keep an eye on their health habits, we as researchers may need to look at emerging technologies to design a system with notifications that reflect the urgency of the matter in a way that fits into the user's busy schedule.

To achieve non-overwhelming notifications, ambient information systems (AIS) can be leveraged, as they aim to portray non-critical information in a form factor that allows for receding in the background when unneeded [62]. Multiple notifications could be conveyed via an AIS at a calmer level than a repeating non-ambient alarm, affording systems more chances to remind the user without messaging fatigue. But, if a user lacks to respond after an ambient notification, it may place them past a health-risking threshold, making it reasonable to then use a more forceful, or even critical, alert. At those junctures, this system should act beyond its default ambient behavior and demand attention. A few studies in AIS have investigated systems that shift between varying levels of intrusiveness [4, 20, 47], but none have explored when participants deemed this shift away from ambient notification as acceptable. Similarly, other studies have investigated whether people prefer ambient versus disruptive notification systems [26, 68], but systems that traverse *between* ambient and disruptive states meld the two concepts, creating new scenarios worthy of their own examination. Hence, we begin by investigating which scenarios are suitable for such escalation with: **(RQ1) When do people accept escalated levels of disruption for health notifications?**

To support this scenario, we characterize the concept of **ambruptive**, or ambient-to-disruptive technology. Ambruptive systems can initially act as an AIS but contains the capacity to escalate its notification if the message becomes more critical, interrupting the user from their present task. However, before we can test the effectiveness of ambruptive technology in notifying users towards their health goals, we must first learn what makes for an effective system that can achieve both ends of the noticeability spectrum, requiring concrete examples to be created.

In designing an artifact that embodies ambruptive technology, we chose to mimic plants as a design motif (Figure 1). Plants are found in many interiors and their presence would not cause distraction, providing a naturally ambient platform to build from. To convert a plant-mimicking object into a notification system, we added mechanisms to turn them into shape-changing interfaces (S-CI) [16], which allowed us to control various motion parameters to perform different scripted movements. Just as living plants move during the day at rates imperceptible to humans, these artifacts could aim to display data without being distracting to the user when such data is non-critical. However, when critical data must be communicated, the ability to deploy "unnatural" shape-change or speeds could allow for a jarring experience that may provide the momentum needed to shift an ambient system into a disruptive one. Our controllable artifacts allow us to probe individuals' reactions to whether this form factor could meet the task of portraying a wide variety in notification levels. This will help us answer a question: **(RQ2) How could varying levels of health notifications be portrayed in shape-changing interfaces?**

With these artifacts, we underwent an exploratory Research through Design (RtD) [79] study with 10 individuals who were currently using a strategy to remind themselves to work on a health-related goal. We aimed to first learn about their current strategies, then introduce our artifacts to gather their impression of the concept and whether it would work in their current health routine. Additionally, by asking their imagined use within their daily lives, we would organically learn: **(RQ3) How do people envision using shape-changing interfaces within their environments?**

In this paper, we detail our design process of creating plant-mimicking S-CIs that embody the concept of ambruptive technology, and the study procedure to show the artifacts' movements to elicit participants' reactions. We report findings on acceptable scenarios to disrupting people for health-related activities. Our artifacts provoked a range of reactions, including how using naturalistic aesthetics led to interpretations of the uncanny and morose, and which ways system physicality affected imagined uses. In summary, our main contributions in this paper are:

(1) The characterization of ambruptive technology: systems with the capability to adapt their notification level throughout the ambient-to-disruptive axis.
(2) The Experience Prototype artifacts we created to embody the novel concept of ambruptive technology. They allowed our participants to experience the unfamiliar concept.
(3) The findings from our exploratory research, including accepted scenarios on ambruptive technology in the context of health notifications and reactions toward our design choices of a plant-mimicking S-CI artifact.
(4) The design suggestions in health-related notification systems and S-CIs, and proposed avenues for future research in ambient-to-disruptive technology.

2 RELATED WORK

To give participants a concrete scenario for the concept of ambruptive technology, we chose a specific context that people could already be familiar with: notifications for health-related activities. In this section, we provide a review of literature that intersects the theme of health notifications with different modes of delivery, especially ambient information systems and shape-changing interfaces. We also cover how plant-like designs have been employed in HCI.

2.1 Notifications

Many studies have looked into how notifications can be combined with personal health data to influence people towards healthy choices [7, 73], or which situations are best for notifying the user [25], particularly in the area of Just-in-Time Adaptive Interventions (JITAIs) [27, 44, 53, 59, 69, 72]. Similar to JITAIs but beyond the health domain, the question of *when* a disruptive notification should occur has been covered broadly, such as the appropriate contexts when interruption is suitable [28, 49]. Our research extends and complements these prior works by examining a novel dimension of notification, that is, the *gradient* in notification portrayed in a physical system such as a S-CI. While our work also does consider timing, we focus on the escalation of a repeated message and when disruption should be judiciously used rather than the tailoring of an initial message's placement based on prior or current data.

Researchers have also looked into the categorization of notifications to determine when people should be disrupted by a message, e.g. by categorization rules set by users [18, 35], or via machine learning to replicate users' prior actions [50]. Although we also investigate decisions people make about notification disruption, we emphasize discerning how individual messages may gain importance based on situation and timing, compared to the prior works that looked at a singular importance categorization per notification.

Interruptions and disruptive notifications carry a negative connotation, and indeed, the negatives of interruption have been well researched, whether physiological and psychological effects on people [2, 32, 78], or its effects on their productivity [11, 33]. However, ambruptive technology does not only focus on disruption, as it employs multiple levels of noticeability, and thus we also reflect on work on the subtler side of notification. Pohl and colleagues charted the region of subtle interaction in HCI [61], specifically with the subsection of studies that aimed for non-intrusive notifications. Similarly, the large design program of Ambient Information Systems mainly targets non-disruptive notification, but in fact supports the concept of ambruptive technology within its definition.

2.2 Ambient Information Systems (AIS)

Although AIS are generally designed to be non-distracting, AIS taxonomies offer a full range of notification levels as a key dimension—both Pousman & Stasko [62] and Matthews et al. [48] list levels of *interrupt* and *demand attention*. Thus, although AIS initially aim to reside in the periphery of users, they do not need to remain there. Little work has been done in designing systems that facilitate multiple notification levels. The Bus LED Display was an example application that flashed its LEDs to change a peripheral display into an interrupting notification, but acted only as a proof of concept and differs from our work in display type (light-based vs. S-CI). [47]. Angelucci et al. proposed an interface that "distracts users only if the severity requires it" [4], assessing mockups that mapped colors to severity levels, in either a horizontal scrolling or tab-based interface. Despite the similar overarching goal, our work differs from theirs in display type (screen vs. S-CI), context (telecommunication network fault vs. personal health), and study design (design and usability study vs. RtD approach).

The AIS space has been paired with a health-related context for multiple studies—a display-only example being Spark's use of informative art to visualize physical activity [19]. Additional studies have investigated further in the ability for AIS to actively promote healthy activity, e.g., Fish'n'Steps using an ambient display to link a cartoon fish's growth and demeanor with a users' footstep count [45], and Rogers et al. investigating three ambient displays intended to promote stairs use versus the elevator [65]. In other health-related avenues, García-Vázquez et al. created three AIS to encourage elders' medication compliance [22], and Wwall encouraged hydration through the use of a display wall [76]. While aimed at assisting similar health goals, these studies all focused on a *single notification level* and did not use notification escalation as our work does. MoveLamp was a study that touched on increasing notification level based on user activity, changing the color and brightness of a light display to promote physical activity [20]. However, it differs from this work both in the non S-CI aspect of the light display, its main focus on behavior modification, and in not focusing on when its participants wanted to be interrupted—instead using a predetermined formula for escalation.

2.3 Shape-changing Interfaces (S-CIs)

AIS and S-CIs have been linked together since *Dangling String* [74], but do not need to coexist. Similarly, ambruptive technology is not limited to systems that use shape-change. However, exploring an abstract concept unfamiliar to the majority of users is a difficult endeavor both for researcher and participant. Therefore, we created a concrete example, in this instance an S-CI, to elicit reactions from users on which scenarios, if any, would warrant an ambient-to-disruptive escalation. Due to our qualitative focus in this study, this work contributes towards understanding the user experience of shape-changing interfaces, one of the grand challenges of S-CI [3].

Specifically looking at indicators for health-related systems, AIS that use shape-change have also been used throughout the years, from wall-like surfaces to portray biometric information [40, 77], or sculptural elements encouraging good posture [26] and work breaks [34, 68]. These share similarities to our work as they examine health-related scenarios, but none consider further behavior when a user fails to respond, and all remains solely on either the calmer side or disruptive side of notification level dimension. Of note is the participant of Breakaway [34] indicating that the system could be easily ignored if she was too busy—based on one's situation, this could be a positive or negative trait. Singh et al. [68] created design probes to explore S-CI notifications for Repetitive Strain Injury (RSI) breaks, having separate disruptive and non-disruptive versions. However, their participants preferred non-disruptive notification, and all subsequent study phases aimed to reduce disruptive techniques. We expand this knowledge in health-related notifications by not only looking at a larger variety of health goals, but explicitly probing when varying levels of disruption would be accepted. This would require the creation of artifacts with the fluidity to move between the ambient-to-disruptive axis as needed.

3 AMBRUPTIVE TECHNOLOGY DESIGN

The concept of ambruptive technology has an inherent conflict: the desire to not overload the user with notifications vs. the desire to ultimately ensure that a user is aware of the need of an activity for their health. Additionally, we must acknowledge the disparate requirements of individuals with different health goals and statuses. With such wicked problems [64], we decided to employ a Research through Design (RtD) method [21, 79] as it would allow us to observe how people react to a concrete portrayal of the unfamiliar concept. Here, we clarify the concept of ambruptive technology by first describing an example usage scenario with current notification technology, and contrast that with the expected outcome of an ambruptive system. Then, we discuss the rationales between various design decisions made in the artifacts we created.

3.1 Example Scenario

Sienna wishes to be reminded to take her medication, which is scheduled every five hours. She loads a medication reminder app and schedules alarms at 9 AM, 2 PM, and 7 PM. At 9 AM, her device chimes with a notification, and she successfully takes her dose. However, at 2 PM, she is in the middle of an important video call and does not notice the notification. As she immediately pivots to an assignment after the call, she does not see the notification until time passes the recommended dosage period. To avoid being overmedicated at her next scheduled time, she skips her dose.

In an alternate timeline, Sienna uses an ambruptive technology system that uses shape-change for notification. At 2 PM, the S-CI subtly begins moving, but Sienna is again in an important video call and does not have the capacity to concentrate on anything else. At 2:05 PM, with no response from the user, the S-CI moves in a slightly more noticeable manner. Since Sienna is deep in thought on her assignment, she notices the alert peripherally, but completion of her task holds higher priority at the time, and she ignores the warning. A few minutes later, again with no user response, the S-CI now chooses a higher notification level and moves with a vibrant, distracting movement—forcing attention, as Sienna is now in danger of missing her medication time slot.

3.2 Design Rationale

3.2.1 Notifications with Multiple Distraction Levels for Wellbeing. Ambruptive technology offers the novelty of persistent alerting with appropriate shifting distraction levels. In the context of health, some activities' guidelines allow for flexibility, e.g., the length of time between medication dosages is given as a range, not an absolute number [31]. Therefore, this system may begin with subtle notifications to inform the user that their activity should be performed *soon*, but not necessarily immediately. As time lapses without activity, urgency increases, and a suitable higher level of notification is authorized to demand user action (see Figure 2). Because such a system requires the presentation of multiple distraction levels, we explore which characteristics help portray this gradation.

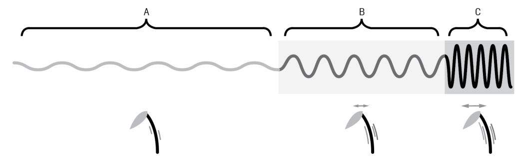

Figure 2: As time without user response grows, notification levels in a system using ambruptive technology can increase in turn. This variety increases the amount it shakes as notification levels rise. (A) Initially, ambient notification suggests "action should be done soon"; (B) as the period of inactivity continues, "make-aware" notification level is used to increase the urgency slightly; (C) the user is now in danger of missing medication window, so "demand attention" notification level with higher intensity in shape-change is issued.

3.2.2 Leveraging the Expectations of Plants. Humans have linked plants with health throughout history and science. For instance, bamboo is a symbol of long life in Asian cultures [43], and the Popol Vuh described plants that acted as health indicators—shriveling and sprouting in tandem with their owner's health [24]. Existing studies in how humans interact with plants have investigated cognitive and emotional benefits received from caring for plants [36], the use of horticulture as therapy [63], and how the presence of even pictures of plants may provide positive mental benefits [8].

We also believed the aesthetics of a system designed to look like a plant could aid in our investigation of ambruptive systems. Today, plants can be readily found in homes and workspaces, and thus these artifacts easily integrate with the expected landscape of the interior. In the same way that camouflage mimics its natural surroundings to blend in, the design choice of houseplant emulation aimed to decrease the obtrusiveness of the interface—in turn increasing the ambient-ness of the system. However, we could experiment with artifact movements that cannot be exactly found in nature, differing by the rate of change or even the actual movement type itself. We saw this greater control as an advantage, as different design parameters may be explored and adjusted easily in a synthetic entity, without being restricted by living growth boundaries. These "unnatural" movement types were meant to explore characteristics that increase the notification level of these interfaces.

Although Human-Plant Interaction [14] has recently been recognized as a topic within HCI and a framework for manipulating living plants [67] now exists, these both deal specifically with living plants and are constrained by the biological bounds of the plants themselves. Along the same lines, the use of living plants has been investigated as a way to notify users of health activity, such as affecting the health of living tomato plants by altering watering and nutrition schedules to reflect changes in Fitbit data [15].

By including artificial plant-styled systems, one can find additional examples in the health notification arena, such as various uses of plants to represent user activity: altering the growth of a stylized representation of a garden [17], or basing the foliage of a virtual tree on a user's hydration habit [39]. Plant-like S-CIs are also well represented: several studies alerted their users of bad posture [26, 29], others used flowers and ivy to aid in the reflection of sedentary behavior [6, 51], and one combined baby monitoring and room control in a design influenced by plants [66]. All these prior works sought to design ambient, non-interrupting interfaces, and focused on investigating the workings of the displays and tracking mechanisms—for example, measuring if users could correlate the various plant representations to the mapped data. In contrast, we examine how systems with plant-mimicking aesthetics may vary their notification levels, and any resulting emotional responses.

3.2.3 Artifact as Experience Prototype. As we are dealing with the health of users, caution should be used to avoid unforeseen negative circumstances with emerging technologies. While other contexts offer a little more leeway—for example, affecting a user's productivity negatively is less damaging than affecting a user's health negatively—research that possibly interferes with the well-being of its participants must tread greater caution.

Additionally, prior work has reported individuals' preference to non-disruptive health notifications over disruptive, specifically for posture guidance [26] and RSI breaks [68]. However, we suspect that people's receptivity to notifications would be highly context dependent. Therefore, an exploratory study was essential to gauge people's tolerance to a system that could escalate to a disruptive notification, and the context where such disruption was acceptable.

Our study approach began with investigating how our artifacts should be designed. These artifacts needed to fill multiple needs: the first to concretely illustrate the concept of ambruptive technology to people, when we could not assume that any participant even had experience with an AIS. A second role was to examine how design choices affected the suitability for a system that provides both ambient and disruptive notification. Creating Experience Prototypes [12] would allow us to gain knowledge towards both topics by enabling the participants to experience these situations themselves rather than imagine an abstract condition.

We simplified the experience by planning to base the notification trigger on participants' real-life scenarios, e.g., medication alerts based on time or activity alerts based on step count. Situating the participant by having them imagine the circumstance where they would normally receive such a notification would allow them to focus on the *presentation* of the notification, rather than initially distract them over *why* a notification was occurring. Our artifact design would then focus on the visual representation of ambruptive technology rather than the algorithms and decisions around actual data, which in turn allowed us to speak to participants with varying health goals rather than just one.

3.3 Initial Ideation and Characterization of Ambruptive Technology

We began with conceptualizing different ways a plant-mimicking interface could be used to represent data, using both sketches and working mechanisms. This led to 25 ideas along multiple categories: **shape**: a change in the overall structure of the plant itself; **orientation**: moving the plant body along different angles or axes; **plant state**: portrayal of different aspects in a plant's life cycle such as health state or fruiting phase; and **external forces**: change to the plant caused by a foreign source, such as weather.

Due to our interest in noticeability, we explored other themes researchers had used in their work in notification systems. Klauck et al. [37] experimented with varying the speed and size of movements and their effect on noticeability, and we planned to represent this in our own artifacts by varying **speed and distance parameters**. When sharing our initial prototypes with colleagues, we noticed that several people mentioned sad emotions from seeing the plant in particular positions (e.g., a drooping plant), and we investigated further into **emotion portrayal** in shape-change. Lee et al. [41] rendered a 3D shape with various levels of bending and convexity/concavity and measured how such poses interacted with user emotional reactions. Strohmeier et al. [71] investigated the correlation with emotion specifically to various shape changes. To gauge user reactions to our attempts in emoting sadness in our artifacts, we decided to use shapes that have correlated to sad emotions—mainly concave poses in a downward position. Finally, we explored cognitive theories on bottom-up **saliency** models mentioned in the psychology field [23, 38], but did not find many examples of what was considered salient—less so in the use of movement or shape change. However, experimenting with various motion patterns led to the accidental discovery of particular movements that led to uneasiness when watched. Intrigued with the effect it had, we decided to investigate naturalness–unnaturalness as another axis to experiment along as a possible use of salient notification.

To illustrate our ambruptive technology concept, characterized as systems with the capability to adapt their notification level throughout the ambient-to-disruptive axis, our artifacts required the maneuverability to portray different levels of disruption. With our three themes of noticeability, we reviewed our plant-mimicking conceptualizations and chose two mechanisms (Figure 4) that could represent different values within the related variables we identified. These would be used to explore how shape-change could be used for both ambient and disruptive notifications, and in turn, capture participants' initial reactions towards ambruptive technology.

3.4 Artifact Construction

Artifact parts were designed in CAD and printed with a FDM 3D printer, with some post-print sculpting using heat. The artifacts were controlled by a Wemos-D1 clone microprocessor development board. Each artifact used custom code specific to its mechanism and was programmed to perform specific scripted actions on trigger. The artifacts can poll a remote web API and retrieve instructions, but for this study's needs, movement was simply triggered over serial communication via USB.

The final version of the first artifact, shake-artifact (Figure 3a), uses a pinion and rack mechanism to shake the leaves of the device, intended to portray wind naturally blowing through the plant (Figure 4 left). Control parameters for the shake-artifact were **distance**: the range of linear movement used by the artifact; **frequency**: how often a shake event occurred, and **speed**: how long the shaking movement's back and forth action should take. With the shake-artifact, we chose a slower, *subtle shake*, and a much stronger *heavy shake* movement as our two possible actions. We note that the names used for the artifacts and movement types are only for clarity in this paper; the artifacts were not named during the study to prevent bias.

The final version of the second artifact, droop-artifact (Figure 3b), manipulates attached monofilament to curl and straighten

(a) shake-artifact (b) droop-artifact

Figure 3: The two artifacts used in the participant interviews. (a) Shake-artifact**'s leaves shake, intended to portray wind naturally blowing through the plant. This artifact was modeled after Strelitzia nicolai, informally named the Giant Bird of Paradise plant. (b)** Droop-artifact**'s stems droop and rise at various speeds on command. The final artifact was modeled after Monstera deliciosa, informally named the Swiss Cheese plant.**

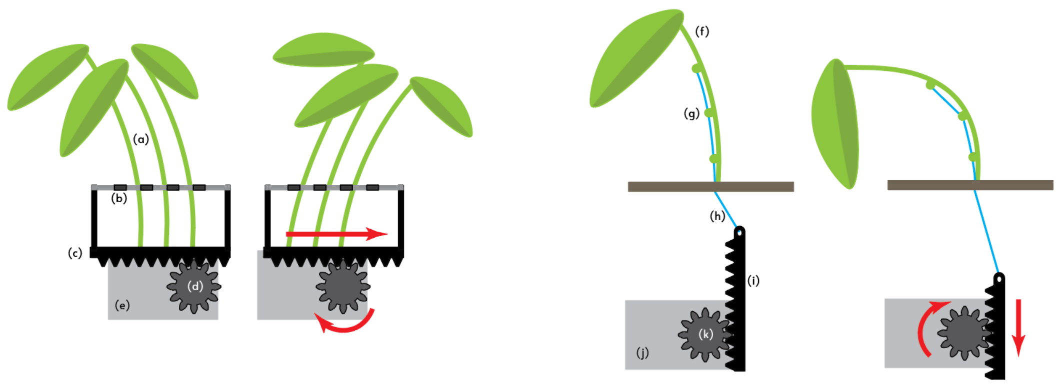

Figure 4: Mechanisms used in our artifacts. On left, shake-artifact**: the plant stems (a) are pushed by a comb piece (b) attached to a rack (c). A pinion gear (d), driven by a motor (e), activates the rack. As the pinion gear rotates, it causes the comb piece to push stems in the opposite direction, and the movement is repeated. On right,** droop-artifact**: the plant stem (f) contains several channel nodes (g) that are connected to monofilament line (h). The line is tied to a rack (i), which is moved up and down by a motor (j) driving a pinion gear (k). As the pinion gear rotates, it pulls the rack down, in turn pulling the line down, also in turn pulling the stem down into a downward shape.**

the plant stem (Figure 4 right). Control parameters for the droop-artifact were: **distance**: the amount that the stems were pulled down or released up; **speed**: how slowly or quickly to take from one position to another; **direction**: whether the movement rose up or down; and **timing**: when to perform a move. Selected movements for this artifact included basic up and down actions at various speeds. We also included four additional scripted movements, meant to delve into different ways movement could be used as effective notifications. *Heartbeat* used a duplicated abrupt start-stop movement to display a tick movement twice. *Hiccup* kept the plant in a down position but would pop up abruptly when trying to notify. *Lift* had the plant move its leaves downward so forcibly that it would lift itself slightly out of its own container. *Panting* used a smooth loop of undulating stems of the plant that was meant to look as if the plant were panting.

4 METHOD

With our artifacts completed, we began planning the evaluation process with participants. Our original intent was to interview participants in a lab setting, puppeteering the artifacts over serial connection to simulate their reactions to the participants' health data. However, due to the COVID-19 pandemic removing in-person options, we instead planned for interviews to be held virtually, over video chat. To share each artifact's movements in the remote setting, we created videos of different movements from each artifact, which we could playback to each participant using a custom web application (Figure 5) we controlled and presented via screen share; this would give a consistent and clear presentation to all participants, compared to a live feed from a webcam. Please refer to our supplementary video to view clips of all artifact movement types.

4.1 Recruitment

Participants were recruited over Facebook and Reddit, email mailing lists, and flyers across a college campus. A total of 169 respondents took a screening survey; 122 did not qualify due to answers or suspicious entries, and ultimately 10 participants were chosen, aiming in diversity of age groups and health goals. The criteria for participation included *(with reasoning for each criterion)*:

- Be 18 years old or older. (The intended population for this study was adults.)
- Have normal or corrected-to-normal vision. (Because we were holding interviews over video chat and presented the artifacts as a video clip, the individuals we would choose needed normal vision to participate.)
- Have equipment capable of participating in a Zoom video chat (computer, internet access, webcam, microphone, Zoom software), and willing to participate with video and audio. (We needed individuals to be able to use the video chat software effectively during the interview, and be willing to be recorded for transcription purposes.)
- Work at least three days a week at a desk for 6+ hours per day. (Because of the physical nature of the artifacts, we needed individuals who remained roughly in one location for an extended time per day, so that interactions would not be missed.)
- Have a health-related goal, which requires acting on multiple times per day (e.g., taking medication regularly, step count goal, hydration goal, taking regular breaks during prolonged sitting, eating meals on a regular schedule). (We wished to have user scenarios where they could be notified multiple times per day.)
- Have prior experience with a strategy to aid in adherence to healthy activity goal (e.g., alarms and reminders, wearable devices like Fitbit, health apps, smart bottles, post-it notes, journals and calendars, pillboxes). (We needed individuals already familiar with using a strategy so we could hear scenarios of current use and compare/contrast with how they imagined they would use ambruptive technology.)

Table 1 summarizes participants' strategies and health goals along with their age range and location. A screening questionnaire, consent form, and sample interview were reviewed and approved by the University of Maryland's Institutional Review Board.

4.2 Interviews

For each participant, we held an hour-long video interview using a semi-structured interview process. We asked the participant to describe their health goals, and listened to the participant's accounts of what strategies they use to keep track of their health-related activities throughout the day. We then introduced the concept of ambient notification by allowing the participants to experience the *subtle shake* portion of the shake-artifact, followed by the *strong shake* movement, an example of escalating notification. After hearing the participant's reactions to these, we switched to the droop-artifact and played the four escalated notification movements: *heartbeat*, *hiccup*, *lift*, and *panting* (Figure 6), then held a discussion with the participant over which movement best represented subtle and escalated notification, and why. While some movements could relate to each other (e.g., the *subtle shake* amplifying into the *heavy shake*), the droop-artifact's movements were very disparate, and so thumbnails of each movement were displayed during the presentation of those videos. Participants were invited to request the replaying of any video during our discussion.

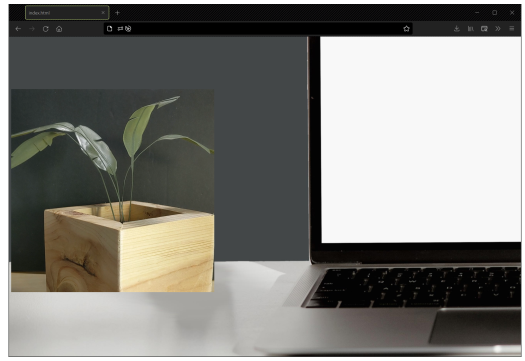

Figure 5: The screenshot of a web application used during interviews to display video of artifacts to participants and situate them in a work-like setup.

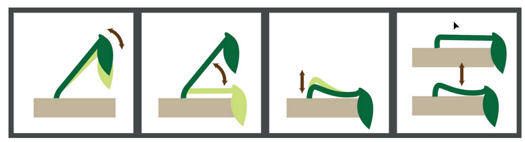

Figure 6: Thumbnails used to remind participants of the various movements used in droop-artifact**'s disruptive portion. From left to right, heartbeat, hiccup, lift, and panting.**

We then explored the plant's capacity of displaying state via shape-change rather than just a notification indicating the need for action. We showed various up and down movements and positions of the droop-artifact, and then asked the participants what they felt was best to display their state in an S-CI. Finally, we followed up with general questions around how the participants imagined these artifacts in their lives, such as choices in location, size, and aesthetics, and explored other features they wished to see.

4.3 Analysis

All interviews were transcribed verbatim, with a light filtering of repeated words and vocalized pauses. We followed a reflexive thematic analysis approach [9, 10], starting with an inductive pass at coding on the first seven interviews. At this point, we began refining and clustering the codes that we had captured, generating broader themes from the data. Using new codes that represented these themes, we took a deductive coding pass against all interviews to continue building our outline of themes, refining as we saw fit.

5 RESULTS

In this section, we share our findings from our participant interviews, answering our three research questions stemming from the topic of ambruptive technology.

Table 1: Details of participants interviewed for study.

	Health Goals	Strategies Used	Age Range	Location
P1	Increase exercise; Drink more water	Apple Watch; notes app, calendar reminders	18-24	USA
P2	Adhere to medication; Track steps/activity; Track mood	Medisafe; Fitbit; Strava; Runkeeper; Daylio app for mood tracking	41-64	USA
P3	1000 kcal in activities per day; 10k steps a day; RHR below 55BPM	Heart rate chest strap; Garmin	25-40	Italy
P4	Stand up and stretch regularly; Adhere to medication; Hydration regularity	Pillbox; sticky notes for medication reminders	25-40	USA
P5	Drink 100 oz of water daily; 10k+ steps daily; Strength training 3x / week	Fitbit; Garmin Watch; MyZone heartrate monitor; calendar to track miles run during training season	25-40	USA
P6	Regular work breaks to prevent RSI; Regular sight breaks; Hydration and meal regularity	RSI guard	25-40	Argentina
P7	Adhere to medication; Monitor weight and blood pressure	Fitbit; automated email reminders	41-64	USA
P8	Close rings on Apple Watch; Maintain or slightly lower weight; Gain muscle	Apple Watch	25-40	USA
P9	Maintain hydration; Meal regularity; 10k+ steps a day	Calendar reminders for water, food, and multivitamins; Apple Health for steps and sleep	25-40	USA
P10	10k steps daily; Active 12 hours daily; Drink 32oz of water daily	Fitbit; planner to track exercise and water intake	18-24	USA

5.1 Interruption Etiquette

Although interruptions are necessary in a notification system, designing interruption that is considerate to one's mental state should be the default when considering a system meant for health-related activities. However, when considering ambruptive technology, this effort increases in complexity, as the designer must consider the balance between the ambient and disruptive states to maximize notification capabilities without annoying users. While interruptability (i.e., when it is appropriate to interrupt) and JITAIs have been investigated heavily, not much work has explored ambruptive notification, especially in the context of notification for health-related activities. Thus, to learn more about the propriety of disruption, in our study we first investigated the question: **When do people accept escalated levels of disruption for health notifications?**

5.1.1 Tolerating Interruption for Health. The importance a user assigned to their health goals made a large difference in accepting interruption by the artifacts. Some considered the severity in missed individual health goals, such as P6 who found interruption appropriate when paired with a stretching goal to help an injury to her rotator cuff she deemed serious. Forced interruption was not appropriate for a hydration reminder, even as she noted dehydration was damaging to her health. Activities that prevent acute injuries are prioritized above others, thus deemed worthy of interruption.

The criticality of *when* a health goal must be done also factored into whether participants felt interruption was warranted, such as P7 imagining a time-sensitive medication: *"... You know, if I'm being told,* 'take this pill or your risk of [dying] is higher. Take it right now!' *Then this thing can wave all it wants, right?"* The more important it is that the activity is done at a specific time, the higher his tolerance for a system that disrupts his life.

Users may also tolerate disruptive notifications if they can easily and quickly recover mentally from a brief interruption, as they may not register the disruption as substantial. Participants mentioned quick tasks like stand-up goals and taking a break to get a drink of water as tolerable interruptions due to their brevity.

5.1.2 Circumstantial Notification. Unlike the previously mentioned single-action activities, some health goals require a larger commitment in both energy and time such as a 30-minute exercise routine. However, sometimes these activities do not fit within one's *schedule* or *state of mind*. Therefore, participants wished for the system to have situational awareness—considering their circumstance as an important factor in deciding when to escalate notification. P9 shared her reaction to a disruptive notification for her exercise goal, imagining two different scenarios:

> *Based on my mood, if I have a lot to do, like a lot of tasks to do and I have no time for my exercise, this might annoy me a little bit. But on a normal day this won't annoy me, it will be pleasant and it will get my attention and probably motivate me.*

Another form of circumstance is the user's *physical state.* As a seasoned *quantified self* user, P3 wished to use his physiological status as a basis to determine when the shake-artifact should escalate its notification when prompting him for exercise:

> *... let's say [the plant] reads my data and then knows when it's best for me to work out ... track the heart rate variability and see that at 5:00 PM I'm ready. And the plant shakes and, I [say],* 'Oh the plant analyze[d] me and says I'm okay,' *so I'm going to work out.*

P3 later mentioned his trust in health-optimizing algorithms calculating the optimal times his body would benefit from activity. Even if this could happen at a random and unexpected point during the day, P3 wished to enhance the results of his workout and thus welcomes an interruption coming from a source he trusts.

5.1.3 Overcoming Inertia. If interrupted while active on a separate task, users may choose to prioritize the task and delay their health-related activity. But if a delay action is offered, it may lead to the activity ultimately being forgotten, such as P2's situation with his medication reminder app: *"I just hit snooze too many times, and it stops and then it's like: oh yeah, I totally should have gotten to that but forgot about it."* P2's app's snooze functionality stopped notifications after a certain number of requests, and P2 lost track of his notification. In comparison, he described how the artifacts could implement a snooze feature with the *heavy shake* movement:

> *...here's the instant that the activity has been requested, here's 15 minutes later and you get a little more excited, and when it gets, you know, 30 minutes, an hour, where you're past due, it's getting very excited.*

This notification escalation pattern would be useful where the user feels their health-related activity ultimately must not be skipped, but understands it lacks strict conditions and can tolerate some adjustability in timing. Notification escalation here can complement the flexibility of a snooze function.

P10 felt the artifacts should actively interrupt her after fifteen minutes of ambient notification about her exercise routine because: *"If I [wait] over 15 minutes, I notice that I usually don't end up exercising at all that night because … it's almost 5:30 you know … that means dinner."* Due to their schedules, some users only have specific blocks of time that are available for their health-related activity. Here, a critical boundary in time determines if P10 will be able to exercise for the day, so notification escalation is warranted to increase the success of her health goal.

5.2 Shape as a Notification

The movements and postures of the artifacts do not impart a literal statement. They are abstract shapes, sans language, and must be actively interpreted by the user. In our interviews, we purposely did not explain what each shape-change was supposed to communicate, leaving their definitions open to the participant's own reactions in order to investigate: **How could varying levels of health notifications be portrayed in Shape-Changing Interfaces?**

To avoid message fatigue, ambruptive systems should begin at an ambient state, and so we first needed to explore how suitable the artifacts were in conveying an ambient message. The artifacts did well in this area; participants considered shape change types with smaller movement ranges, smoother actions, and reduced movement altogether as suitable for ambient messaging, especially *subtle shake*. Conversely, for the most part participants felt movements with larger sized actions, such as *hiccup* with its broader up and down action, gave the best opportunity for a notification to be noticed as an escalated attempt. Participants also liked how the *subtle shake* movement led into the *heavy shake* when escalating—seen as an easily understandable progression from ambient to disruptive, as compared to some of the other varied movements that the droop-artifact was capable of. Designing the artifacts to study participants' reactions around emotion and saliency ended up resulting in deeper discussion around the interpretation of abstract movements in a plant-like object.

5.2.1 The Human-Plant Relationship. The relationships between humans and plants cover a broad spectrum of living, whether the link between a farmer and their crops, or simply someone owning a houseplant for decorative purposes. These varied relationships were reflected in the ways the participants spoke about the plant-mimicking artifacts we presented. As humans learned how to domesticate plants, knowledge grew about their signals of health and how actions towards them affected their growth. Participants referred to this generalized knowledge when interpreting the artifacts' movement into health-related notifications, such as P7 discussing how droop-artifact's upward positioning would be interpreted: *"Healthy is what most looks most like a real plant, which is probably the up position, but it could easily involve the color, or perhaps, how saggy it looks, how plants get dehydrated or desiccated or whatever."*

5.2.2 Expectations of Naturalness. Designers often represent a product's "natural" quality with a portrayal of a plant, e.g., a leaf icon indicating organic and natural ingredients, and similarly many participants noted the pairing of our plant-like artifact with naturalness. However, we also found an inverted expectation: participants wanting something mimicking a plant to have natural characteristics, i.e., a naturalistic movement, such as P1 complaining about certain movements being *"a little robotic. It doesn't seem natural for a plant to move like that … there has to be some element of like natural, naturalness, if I'm going to get it."*

In other movements, the elasticity of the artifact's plastic parts sometimes led to unintended resonant movements, such as a leaf continuing to wobble after its actuating motor had stopped. This too was described in negative terms such as *"unnatural because it kind of had a jerky movement"* (P8). Here, the lack of precision in the movements resulted in distracting wavering movements. Although some plants do have visible movement in nature, like a Venus flytrap closing on its prey, such natural movements are smooth and measured, unlike the artifacts. In the same way poor audio fidelity can easily be perceived as abnormal, poor movement fidelity can also give an unnatural quality.

5.2.3 Culpability as a Caretaker. In many cases, participants felt empathy towards the artifacts due to their interpretation of the shape and movement. Several of the droop-artifact movements consisted of the plant leaves being in a downward position, and participants interpreted this as if the plant were dying (Figure 7). As a result, many felt dismal emotions towards seeing plants in that state, to the extent of not wanting to use the artifact, such as P4: *"I would probably just [turn it off] or like I just stop using it because I feel depressed."* and P2: *"the plant just looks so sad … like having that on my desk would be not aesthetically pleasing. I'd be feeling like, oh God, I've killed it."* Although participants did find it easy to correlate a dying plant with an unhealthy health situation, the emotions they felt overrode any usefulness of the natural metaphor to the point of an unwillingness to use such a system.

However, when asked if an abstract, non-plant-like system would elicit the same negative reaction, participants noted that the same mechanics with different aesthetics would be fine, like P6: *"Because*

Figure 7: The downward position of the droop-artifact, interpreted by many as the plant "dying."

that thing won't be dead for me, right? It won't look dead." The artifacts' plant-like form factor held importance in how the data conveyed through shape-change was perceived.

Why would an object hold such an emotional pull with participants? Some reflected on their current relationship with plants to explain why the downward position would not work, such as P10: *"As someone who has a lot of plants, at the sight of like wilting leaves, … it makes me kind of upset, because I take care of my plants and like I hate when they look like that because that, you know, they're not doing well."* The caretaking role that participants held in the past with plants extends towards the plant-like artifacts, perhaps heightening any reactions they may have towards these S-CIs.

Attempting to motivate users by eliciting emotion was not limited to time-based notifications. During the discussion on how the droop-artifact could use its level of droop to indicate the state of a user's health goal progress, some participants also referred to a threshold for which a plant's shape could continue to motivate them to do any action. If the system used a restoration motif, i.e., health-related actions raising the plant from a downward state to an upright state; even with the knowledge that their actions could restore the plant back to an upright position, P2 imagined not finding the motivation to try, *"If I need to do a ton of stuff, and it's already dead then, yeah, it's sort of like, oh well, try again tomorrow."* A similar downward position from the artifact had him mention, *"this gives me no hope that I can ever make it feel better again."*

5.2.4 Uncanny Xylum. Interestingly, some artifact movements induced even stronger negative reactions than the general moroseness over the artifacts' state. This was especially with the *panting* movement, which caused several participants to mention feelings similar to the discomfort stemming from the uncanny valley [52], but here towards a non-human figure, for example, P4: *"I feel like it's similar to like human's movement, but it's not. So, it will somehow give me that kind of like scary feeling."* Many explained their reaction in the context of how they expected plants to act: *"… I haven't seen plants move like that. I'm like, that seems unnatural."* (P5), *"… usually plants won't shake like this"* (P4), and *"It's shaped like a plant but it's not acting like a plant … "* (P7). These uncanny reactions seem to stem from a **representational dissonance**, that is, the discomfort when an object's actions clash with the appearance-driven expectations of the object. In this case, the participants' expectations of a plant-like object conflicted with the movements we had programmed into our artifacts, and thus unease occurred.

However, it should be noted that although uncanny feelings were evoked with the artifacts, these were not universally held reactions. For instance, even though P1 also saw anthropomorphic qualities in the *panting* movement, she instead described it as *"relax time. Like, you know, it's time to focus on yourself."* She explains her reaction further with: *"… like I said, it looks like a massage … Because it reminds me of a motion I already do."* The personal history and experiences of each user could greatly influence how each abstract movement is perceived, in the same way abstract Mark Rothko paintings causes some to weep [30] while others may dismiss them as boring splotches of paint. Allowing users to configure which movements are used by the artifacts seems like a necessity.

5.3 Existing in the Physical World

As S-CIs, the physical aspect of the artifacts we created led to various discussions on how such devices could work in the lives of our participants. Although S-CIs have existed in literature for decades, they are still an uncommon sight in most homes. However, other devices have recently populated the home in the form of voice assistants, and users are now familiar with interacting with computing without looking at a screen and placing a standalone physical device in one's environment. Our study provides a current look at participants' reactions in the post voice-assistant world to answer: **How do people envision using Shape-Changing Interfaces within their environments?**

5.3.1 One Space, Many Roles. One theme throughout the interviews was the desire for the device to have multiple purposes. P10 described some of the characteristics that would be ideal in an artifact: *"And if you want to like have less clutter and everything, it's nicer if one plant can do all those different functionalities. And then in terms of like money, like buying, you know."* The weighing of several costs, both in physical space and in finance, led to her preference for a multi-functional artifact that could accomplish more than one thing. Some participants suggested expanding functionality by portraying multiple health statuses in one plant. P9 designed a system providing a glanceable display of her progress, with individual leaves representing different trackable datasets. P7 suggested an artifact that would summarize his overall health with one mechanism, where specific shape-changes would act as a nudge to review detailed information in a supplementary system.

However, expanding the number of notifications was not the only way to add functionality. The item's aesthetics were also considered a secondary use, such as in P5 calling the artifact a "triple win":

> *… it looks nice, and it will tell me what to do or notify me subtly, and that notification helps me for my health goals. That's like a triple win.*

She explains further on how she imagines using it: *"I would want to put this on my desk versus … hiding it away. Because that's one of the challenges with all these trackers, right? Like you could buy them but never use them and it would be in a drawer."* Because the decorative aspect of the artifact holds utility in making the area more pleasant, P5 feels she would find herself continuing to display it, unlike other health tracking aids that she has hidden away after disuse. Similarly, P9 *"would treat this as a plant"*, i.e., keep it out on display, when not deciding to use its notification capabilities. Thus, disparate purposes of a system allows for **disinterest buffering**, or a secondary aspect providing reason to continue use of a system when its user’s interest in an initial aspect of the artifact wanes, and vice versa as the user’s focus changes over time.

5.3.2 Fitting into the Environment. Participants desired an object that united into the existing aesthetics of their room and made decisions on shape to unify with their decor, for instance, wishing to match houseplants that were already in their environment. However, when asked of an unstyled variant, such as a simple flag mechanism, some participants rejected the idea outright, requiring some form of design aesthetic. Participants liked the naturalistic aesthetic of our artifacts, even if they were unfamiliar with plants. Size was another element where the artifacts’ environment determined form factor. Participants adjusted their preferred artifact size to the space it would reside in, whether small enough to fit on a crowded desk, or big enough to be seen in a large room without overwhelming it. Furthermore, participants noted how choices made for the home could differ from those for an artifact placed in the office. Some examples given were the need for a more muted design in the office to match the existing neutral decor, or the need for a more noticeable movement at home because of the likelihood of other belongings causing their own distraction there.

5.3.3 Environmental Interference. With the subtle version of the shake mechanism, modeled to look like a slight breeze passing through the plant, several participants noted how the environment itself might interfere with the interpretation of the artifact. P5 described a scenario: *“So, like if someone walked by and I saw it move: was it moving because I need to move? Or because someone walked past fast enough to move it?”* Because air currents are actually part of the environment these artifacts would live in, the naturalistic subtle shake movement might have been *too* naturalistic, having participants wonder if the movement was caused by the system itself, or by some other common external force.

5.3.4 When Everyone Sees Your Notification. The workplace was imagined as an ideal location for the artifacts by many participants. However, some noted how a shared environment leads to a personal notification turning into a broadcast notification, as anyone within sight of an artifact could notice its movement. Regardless, many had no concern with informing others of such a device and its purpose. The artifact might provide a conversation piece or a way to share their health goals with others, if they choose. If people wished to keep their health status private, the non-literal, abstract shape-changing notifications used by the artifacts gave participants a sense of privacy if desired. Several mentioned how others would not be able to initially decipher how the artifacts’ movements related to their health goals unless this was explained. This privacy via obscurity was especially appreciated by P5, who considered fitness a "personal journey" and the ability to keep one’s related health data private was a welcomed benefit in using S-CIs.

However, notification escalation could attract attention, regardless if others understood the message. P2 described discomfort with an elevated notification being visible to others: *“Obviously [if] we’re in an office and that’s happening with somebody sitting across the desk from me, that [could] get weird fast.”* On the other hand, P2 also indicates how the knowledge of notification escalation could be a form of impetus itself: *“I think if you’ve got somebody in the room with you and it starts, probably more likely to also react to it sooner because you know what could be coming.”* Here, the more subtle notifications insinuate a second message beyond a reminder of one’s health goal—a possibly embarrassing escalation or a situation that could annoy others if one does not act. Publicized notifications could leverage social etiquette, if the user feels it is effective.

5.3.5 Reinforcing Locations. Location, by itself, can provide a reminder to people about their health goals. For instance, P1 explained how entering her kitchen was all that was needed to prompt herself on her hydration goal: *“... whenever I’m downstairs in the kitchen, I just kinda remind myself: drink water.”* As the artifacts were physical items unencumbered by the confines of a screen, unlike standard screen-based notifications, they innately have the ability to be placed where they can accentuate these cases of “locations as a reminder.” A natural pairing is to place the artifacts in areas where the health-related activity is actually done, e.g., inside the home gym. For instance, P1 imagined the owner of a home gym using the artifacts to measure their activity, and others noted the dining table because their food routines were paired with health-related activities (e.g., medication, diet maintenance).

Participants also considered placing the artifacts in areas where one was known to lapse from their health goals. P8 chose his desk as a suitable location, as *“because I’ll be sitting at my desk and that’s when I miss my stand-up goals.”* P7 imagined how using an artifact next to the television could affect unwanted binge-watching:

> *... if you want to be reminded, for example, not to watch TV for too long without getting up and moving around ... you might put something like this up next to the television, and you know, you zone out and you’re watching show after show—it just starts waving more and more.*

Instead of a system prompting users towards an action, P7 conceptualizes the placement of the artifact to disrupt the ability to continue an activity. Using a system that can combat “bingeable” content via its own attention-seeking disruption may be a natural and effective pairing, and the freedom of a S-CI allows users to place the system in the most effective spot.

6 DISCUSSION AND FUTURE WORK

This research aimed to explore the initial reactions of users to ambruptive technology in the context of notification for health-related activities. In this section, we consider areas of caution and provide insights in designing physical systems like S-CIs, and offer avenues for future research in ambruptive technology.

6.1 Roots of Negativity

One interesting finding was the strong negative reactions to various movements and poses in our artifacts. This ranged from the sadness felt upon seeing the droop-artifact in the downward position, to the unsettled feelings when viewing movements that caused representational dissonance.

These negative reactions show how designers must consider more than mere interpretability in notification systems. Although the poses of the droop-artifact could successfully be interpreted by participants as representations of their state, the emotions and feelings that resulted from this interpretation caused them to reject the use of the system. This reflects how users avoided Fish'n'Steps if their activity led to a sad fish display [45]. While this study extends that work by reporting how some of these feelings stem from the caretaking relationship between humans and plants, but not in a non-living representation, future work could look into when an object's aesthetic crosses the boundary from an independent object that does not rouse any empathy, into a "thing that is cared for." Learning more here could reduce cases where participants discontinue use of systems because of the adverse emotions that originate from their design.

Furthermore, although others have looked into creepiness and HCI [75], especially in the case of humanoid robots and the infamous uncanny valley, to our knowledge this is the first work that found inherent uncanny effects in a non-zoological representing entity, i.e, eeriness from the object's own actions rather than from a perceived external force such as Living Room [5]. Future work could explore the precise factors of these artifacts that caused this discomfort, as this study was not focused on exploring the root causes of these emotions or measuring the effects of parameter changes. Nonetheless, using plant-like artifacts to explore uncanny reactions may be useful in future experiments where removing the zoomorphological factors could help isolate certain factors.

It is unknown how the reactions we found relate to those stemming from the uncanny valley theory. As the uncanny valley explores the axis of realism, it would be interesting to see if adjusting the realism of the artifacts affected the uncanny reactions. We designed the artifacts with realism in mind, but would the presentation of a more realistic, less realistic, or even cartoonish plant change people's reactions? Additionally, not all participants found the same revulsion towards the *panting* movement, and few even reacted favorably towards it. Another avenue of exploration would be into which prior experiences cause people to react positively to artifacts that normally invoke feelings of the uncanny to others. Could increased exposure of something change the response of users who initially feel some revulsion to a movement? Extending on this idea, would it be more worthwhile to learn how to nullify the uncanny valley reaction rather than traverse the steep levels of achieving true realism in robotics?

In addition, the growing interest towards investigating the interplay between humans and plants cannot be ignored, whether plant-mimicking systems as ours or those that manipulate living flora directly. With both Human-Plant Interaction [14] and studies that deal with artificial plants, further research to understand the reactions of users towards systems that use plant motifs will be key in ensuring successful outcomes.

6.2 Effective, but Healthy?

In investigating three avenues of notification—speed and distance parameters, emotion portrayal, and salience, we found that all three had at least one movement type that was described as effective in prompting the participant to act. However, as the previous section discusses, some prompts were coupled with discomfort. As designers, if we solely look at the analytic results, we might miss these negative emotions that arise from the product due to the user still reaching the end result we aimed for. But is this *healthy* for the user? Are guilt trips, uncanny unease, and morose reactions worth it if the user still acts towards their health goal, or could this be more damaging to them mentally, nullifying any gains from their activity? Especially in the health-oriented sector, we feel this question of what additional mental effects could emerge must continually be reviewed when investigating new technologies and techniques, such as Owens & Cribb's investigation into personal autonomy with wearable technologies [58].

Long term negative effects of technological aids must also continue to be studied. For instance, literal crutches aid in the prevention of further damage to a user's leg, but over time may cause shoulder injuries with prolonged use [56]. What are the long-term effects of using technological crutches to aid users in remembering their health activities? Is reliance on technology a gain or loss in the overall health of a user? Again, future work should look into this area to ensure we are net positive in our users' health.

6.3 Designing for Shape-Change

6.3.1 Designing for New Locations. Although the interviews revealed interesting use cases for S-CIs in location enhancing notification, it must be noted that the current artifacts' design may not work well for some situations. For instance, although the dining table is a spot where many health-related activities occur, it is not a location conducive to a wired device. Designers of S-CIs to be used in new locations could benefit from additional engineering to ensure that the devices elegantly fit within one's space, whether this means having a completely cable-free device using wireless power transmission, or perhaps introducing electronic furniture standards with inductive power on their surfaces.

6.3.2 Materiality and Durability. The interviews also revealed interesting reactions on the material and design of the S-CI artifacts. We chose to use thin plant stems on our artifacts both aesthetically, to match the look of real plants, and practically, to limit the torque needed in the motors we had used. However, this led to a number of problems: unwanted movement when the flexible stems wobbled after the direct actuation stopped, users questioning if any movement was intended because it looked as if air currents in the environment could move it, and users apprehensive that continued movement would break the artifact itself.

Future designers should consider designing S-CIs with unambiguous movement as a goal; designing not only how an interface moves, but also how it stops moving. Users should be certain that any shape-change was intended by the systems. Solving this problem could be an exploration of different materials or changing the mechanism away from one that relies on material plasticity. Designing systems with a sturdier look could reduce both incorrect interpretations of unintended movement and fears of fragility.

Several participants expressed concern that their use of the artifacts would be damaging to the item itself, due to how they interpreted the form and materiality of the stems. Exploring how fragility and damage-prevention discourages usage might also be an interesting area to explore in HCI. For instance, designers add weight to physical products to make them seem more durable—is there an equivalent in UI, and would that encourage use of a widget? In a broader take, could a pristine empty state UI actually be repelling users from performing actions because it could "damage" the balance of the screen once data is represented?

6.3.3 Aesthetic Tastes. Aesthetics were considered a secondary use of the artifacts that some imagined would keep these systems in their environment, even if not using them for their notification ability, as its decorative nature provided enough utility. This differs from systems that do not offer any secondary usage and may be "put away" when use is discontinued. Beautifying the environment allows these systems to inhabit valuable physical space that keeps these objects in sight by their owners, which has several advantages. Remaining conspicuous alone could act as a passive reminder of one's health goal, even if active notification is not occurring, as a user could be reminded of the original reason of the object whenever it was seen. It also continues to occupy a spot in users' environments that makes re-continuation of the system convenient for the user. Thus, the aesthetic utility of the object can act as a buffer against temporary disinterest, and thus extend the overall lifetime of the system. This concept of **disinterest buffering** may be another area that could be investigated further both in the context of health and outside of it, and may be a useful design strategy when dealing with activities that are known to have cycles of use and disuse.

6.3.4 Designing for Privacy in the Open. When S-CIs are used in a public setting, their messages are essentially broadcast to all, which may or may not be desired by users who consider their health a personal journey. Currently, the abstraction of the artifacts' S-CI movements offer privacy via obscurity, but this may not have a lasting effect if similar systems become more commonplace. Additionally, designers should also consider the needs of non-users: those in the surrounding area who are not contributing data or benefiting from the system. Unwanted notifications could be a form of intrusion, especially if escalated to a disruptive level.

Thus, future designers should consider the privacy of users' data in conjunction with giving non-users privacy from intrusion. Both may be achieved by designing S-CIs with a public face for others and a private view for the user. For instance, if continuing with the plant motif, public facing portions of the plant could be used as a visual hedge, hiding the notifying portion from others while also preventing unwanted distraction to others. However, additional work is needed to learn how non-users feel about systems that broadcast to the public space while holding no relevance to them, and may pull from social and industrial-organizational psychology to study these societal questions.

6.4 Differences in Findings Towards AIS for Health

In the context of RSI breaks, Singh et al. (2021) examined mainly non-disruptive notification after they learned participants' preferences in the earlier phase of their study. As non-disruptive is only one end of the spectrum our study has explored, their findings cover a subset of our findings, having some related themes around the calmer side of notification but with differing and additional aspects. Table 2 summarizes the overlap describing both similarities and differences. As our study investigated a broader spectrum, our findings include many unique aspects we reported in the result section, i.e., all aspects under the Interruption Etiquette theme, most aspects under the Shape as a Notification theme, and the Reinforcing Locations aspect under the Existing in the Physical World theme.

Reasons for the differences could be as simple as the variance of individuals in each participant pool. However, their study both used co-design and encouraged the selection of items already familiar to their participants—these two personalization-related factors could plausibly have also affected the relationship participants felt towards the S-CIs. It would be worthwhile exploring further whether personalization affects the **avataric designation** of notification systems—that is, how people cognitively categorize their systems in relation to a representation of self. Even broader, the exploration of how study motif may affect results could help situate future findings and add awareness of result bias.

6.5 Study Limitations

Our study was an initial look with a limited set of participants who were already familiar with using systems to notify them regarding their health-related goals. Future research could broaden the participant pool and investigate if the scenarios identified as being worthy of an interruption also apply to other health goals or people with no experience in health-goal notification. It can be assumed that many in the world's population do not use systems for their health-goals notifications or may even have health goals at all. Viewing how users who are new to health-goal notification or tracking and investigating their reactions to ambruptive technology will help the community understand how prior experience in such systems affects one's reaction.

Additionally, our study participants did not have disabilities, severe illnesses, or age-related disorders, but interviewing those populations or possibly their caretakers would be worthwhile to learn how ambruptive technology could work in their situations. Would users with more serious health concerns have a different position on when notification escalation is warranted? For caretakers, when health-related notifications are not for you, but for someone in your care, how would that change how notification escalation is received? Ambruptive technology could reduce the mental overload of monitoring a patient by the initial use of ambient notification, while providing a safety measure in the notification escalation ability if an ongoing situation reaches a critical state, so these situations are well worth the effort.

Practicality forced some aspects in the design of this study to be fixed, such as the specific shape change types used by the artifacts. However, ambruptive technology is a much broader area than what these artifacts cover. Further work could also look into decoupling or remixing the various design elements and technological areas in these artifacts, and investigating any resultant changes in user reaction. For example, if the S-CI aspect of an artifact was removed, how would users react to a screen-based ambruptive system with plant-like design? Or, how much would abstract sculptural design rather than plants change user reactions?

Also limited were the methods of noticeability that we chose to examine in this study. Because our focus was to capture initial reactions to the concept of ambruptive technology, we chose a concrete subset of disruption strategies that could represent the concept. Future work could look into different means of disruption, whether choosing new movement types, or even implementing

Table 2: Comparing Singh et al. (2021) against the subset of our findings on non-disruptive notification.

Theme	Similarities and Differences
F1: Disruption and Social Barriers	*Social Barriers* theme relates to our *"When Everyone Sees Your Notification"* theme; we add scenarios and depth. Their *Workflow Barriers* theme strengthens the need for ambruptive technology, showing how work needs can preempt health tasks.
F2: Peripheral and Ambient	Aligns with initial ambient state of ambruptive device
F3: Slow Interaction	Aligns with initial ambient state of ambruptive device
F4: Playfulness	N/A, theme not discussed by our participants
F5: Emotional Engagement	Both participant groups assigned emotions to the systems' shape-change. However, their participants sought an emotional attachment to the objects to soften the notification and decrease annoyance, whereas our *"Culpability as a Caretaker"* theme found how the caregiver role recognized by our participants amplified the negative emotions portrayed by our artifacts' notifications.
F6: Motivation and Care-Giving	Related to our *"Culpability as a Caretaker"* theme, but their participants felt "taking care of something meant taking care of themselves," whereas our participants did not make the same link between self and system.
F7: Self-awareness	N/A, our participants did not view the artifacts as a representation of self
F8: Visualizing the Consequences	N/A, our participants did not view the artifacts as a representation of self
F9: Fading Novelty	N/A, theme not discussed by our participants
F10: Practical Constraints and Multifunctionality	Related to our *"One Space, Many Roles"* and *"Fitting into the Environment"* themes, but their participants preferred altering pre-existing items on their desk, while our artifacts would add new decor which our participants deemed still worthy of ownership.
F11: Physical Dimensions	Similar to our *"Fitting into the Environment"* theme
F12: Aesthetic Values	Similar to our *"Fitting into the Environment"* theme
F13: Personal Preference	Similar to our *"Fitting into the Environment"* theme, but their participants' designs correlated with already familiar items, while our participants accepted our plant motif irrespective of their familiarity with plants.

modes aimed at other senses, such as light or sound. This work should also examine if these new disruption types would change reactions to ambruptive system.

Our study occurring during a pandemic forced us to hold our interviews via videoconference, which meant participants were reacting to 2D video representations rather than the actual live artifacts. This representation may have altered the reactions from the participants but we do not know of prior work comparing the emotional arousal from 2D video vs. in-person portrayal. However, our opinion is that participants reacting toward this restricted interaction strengthens the findings, and live, in-person interaction would likely show stronger reactions to the artifacts. When safe, future studies in ambruptive technology should include in-person elements to further validate our findings.

Finally, we chose to perform an exploratory study in order to gauge the receptiveness of ambruptive technology while removing the risk of introducing health related issues. Although we were able to explore how people initially react to ambruptive technology, these findings cannot immediately be extrapolated to predict extended usage, and so further research is needed in-the-wild to continue assessment in this space.

6.6 Toward Realizing Ambruptive Technologies In-The-Wild

Our study uncovered an important factor that would have interfered with an in-situ study: morose and uncanny reactions to the artifacts' movements prompting participants to end usage. Future studies looking at shape change must include an onboarding process to allow participants to personally confirm that the system's movements are considered at least neutral, preventing emotional discomfort from use and possible discontinuation.

Next steps should also involve finalizing some technical portions and design decisions to ready the artifacts for use as a research product [54], allowing the concept of ambruptive technology to be tested in-the-wild. This includes adding backend infrastructure to data from sources such as health trackers or a user's medication schedule, which would allow these systems to run independently of researcher steering. Given participants' desire for circumstantial notification, this work could be combined with current research on interruption suitability and JITAIs to help with the placement of notifications. Once these factors are in place, the in situ study would be able to continue work in this area, observing how participants act when using ambruptive technology in their daily life. A prolonged study could give insight into how users adapt to the technology over time, whether this alters their health goal success, and the overall suitability of ambruptive technology towards activities that must be done, perhaps not immediately, but *eventually*.

7 CONCLUSION

In this paper, we explored the concept of ambruptive technology: systems that can adapt notification levels from ambient to disruptive. We employed a Research through Design approach by first examining key design dimensions to create a set of plant-mimicking S-CI artifacts that offered a variety of movements, then investigating reactions of users to the concept and suitability of such artifacts in the context of health-related activity notifications. Our findings include participants' opinions on when notification escalation is acceptable, how various aesthetic choices influence the interpretations of our artifacts' movements, and insights on designing for physical systems such as S-CIs to fit users' environments. We also offered design suggestions in health-related notification systems and S-CIs, and discussed future research in ambruptive technology.

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