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Go and Grow: Mapping Personal Data to a Living Plant

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ABSTRACT

Motivation is a key factor for introducing and maintaining healthy changes in behaviour. However, typical visualization methods (e.g., bar-, pie-, and line charts) hardly motivate individuals. We investigate how a plant—a living visualization—whose health relies on the plant owner's level of activity, can engage people in tracking and self-reflecting on their fitness data. To address this question, we designed, implemented, and studied *Go & Grow*, a living plant that receives water proportionally to its owner's activity. Our six-week qualitative study with ten participants suggests that living visualizations have qualities that their digital counterparts do not have. This includes people feeling: emotionally connected to their plant; sentiments such as pride and guilt; and responsibility towards their plant. Based on this study, we introduce the Goal Motivation Model, a model considering the diversity of individuals, thus supporting and encouraging a diversity of strategies for accomplishing goals.

CCS Concepts

•**Human-centered computing → Information visualization;**

Keywords

Fitness, Living Visualization, Personal Visualization, Plant.

1. INTRODUCTION

Citizens of industrialized nations are subject to sedentary behaviour (prolonged sitting at home, work, or in cars) which can lead to health complications such as obesity [13]. Adopting an active lifestyle is difficult [24], but the simple act of self-monitoring can lead to healthy behaviour change [33]. More and more people are now self-monitoring with the emergence of tracking devices which measure health data (e.g., steps, calories, and heart rate) [33]. However, the typical way of visualizing such data is through standard bar and line charts, which hardly motivate people [1]. Finding motivation is key to ushering in behaviour change [20]. Thus, visualizing activity data in engaging ways has been studied using e.g., virtual metaphors [6, 22], physical metaphors [17, 19, 34] and video games [2, 26]. We explore living visualizations to extend this trend.

Figure 1: The Go & Grow system linking individuals' activity data to the amount of water that their personal plant receives.

While Personal Informatics (PI) tools typically rely on one's self-motivation, we relate the health of a plant to one's activity level. Taking care of a plant can be a strong motivation to maintain healthy activity levels. Constant watering is crucial for a plant's longevity, but a single day of under-watering will not result in its death. Likewise, people need regular exercise to remain healthy.

Based on design criteria gathered from existing literature, we implemented *Go & Grow*, a computer-equipped cyclamen flowering plant that waters itself different amounts of water everyday according to one's progress towards a daily step goal (see Figure 1). By stimulating the plant with varying amounts of water, the plant becomes a living visualization of the individual's step data.

Results from a six-week long qualitative study indicate that participants gained an increased awareness of their activity level and adapted their daily behaviour. They developed feelings that standard visualizations may not trigger: emotional connection to the plant, pride, guilt, and responsibility. We further introduce the Goal Motivation Model, composed of four levels of goal abstraction surrounding individuals who track their fitness data. We discuss how this model considers the diversity of individuals, and thus supports and encourages an array of strategies for accomplishing goals.

2. BACKGROUND AND RELATED WORK

The emergence of personal trackers has prompted the research area of PI. PI focuses on helping people make use of personal data (including fitness data) for self-reflection, gaining self-knowledge, and making actionable decisions for healthy lifestyle changes [20]. However, previous work in PI has shown that designing tools that help people make lifestyle changes is difficult [20], and that people quickly stop using activity trackers. In a recent study, 65% and 75% of participants stopped after two and four weeks respectively [32]; this happens regardless of fitness change [33]. This may be explained by difficulties from finding motivation and interpreting visualizations hindering people from continued use of PI tools [20].

We review research from Information Visualization (Infovis) and HCI that relates to *engagement* as a strategy for motivation, and describe work that inspired us to use a living plant as a visualization.

2.1 Engagement as a Source of Motivation

Engagement is a broad term which, in our context, we define as *a state of emotional involvement that leads one to commit or invest in a certain activity*. Ideally, engagement leads one to commit to an activity in order to achieve or maintain good fitness levels.

Engaging through Personable Visualizations. One way of engaging people with their data is to provide them with insightful and personable visualizations. Infovis is well suited for this, as its purpose is to help people to gain insights about data [28]. However, applications for individuals who track their own fitness data have different goals and criteria from traditional Infovis applications—which focus on supporting experts working with large amounts of data. Efficiency is not necessarily the measure of success for personal or casual visualizations [15, 30] intended for use in everyday life. Instead, other factors such as motivation, aesthetics, playfulness and pleasure are essential [34], as these can engage people in exploring their data, in having moments of self-reflection [21, 35], and in gaining insights in non-professional contexts [31].

Companies such as Fitbit and Garmin provide online dashboards for visualizing fitness data using standard visualizations such as bar-, pie-, and line-charts. While these visualizations may be simple enough to be understood by most people, they do not seem to be motivating, as people quickly stop using them [32]. In contrast, non-traditional or abstract visual representations (i.e. without precise numbers) improve people's awareness of their data [5]. This is confirmed by evaluations of technologies such as: *Ubifit Garden* which uses a virtual garden to motivate people to be more active [6]; and *Fish'n'Steps* which uses a virtual fish and tank to convey step counts [22]. Abstract visualizations can also provide a sense of privacy while still conveying high-level information [1].

These observations suggest that *personable visualizations*, which are both personal *"interactive visual data representations for use in a personal context"* [15] and *affective* because they are pleasant and likeable, are a promising avenue for motivating people in collecting and reflecting on their everyday life data.

Applying Cognitive Behavioural Strategies and Social Context. Goal-setting [23], self-assessment, and monitoring of progress [10] are well-known cognitive strategies to help people in behaviour change. In an HCI context, such strategies can increase people's awareness of their data and motivate them to exercise more [11].

Berkovsky et al. [2] used virtual game rewards in exchange for physical activity, and Nenonen et al. [26] used real-time heart rate data to control an interactive biathlon computer game. Both showed that goals and achievements can encourage people to be more active.

Industrial technologies (e.g., Fitbit, Garmin) focus on using cognitive behavioural strategies with social media and data sharing to motivate people to increase their activity levels. Consolvo et al. [3] found that groups of friends sharing their step counts over three weeks in order to achieve a group goal increased their awareness and gained more motivation to exercise. This may be due to the positive impression people want to maintain in their community [33].

Inciting Emotions. HCI and Infovis researchers have found that emotions can engage people with data. Affective expression of representations is a factor of engagement [25] and emotions can evoke affective experiences [7]. This is echoed by studies related to activity data. For example, Tong et al. [36] developed a game that connects the health of a virtual pet with the owner's physical activity. Participants in their study developed a *connection* with their virtual pet and felt the need to be more active. Similarly, many participants in the study of *Fish'n'Steps* exhibited emotional attachment to the virtual organisms visualizing their step counts [22].

Norman argues that one's affection for beautiful things is crucial to engagement, interest, and pleasure [27]. Plants are enjoyed for their aesthetics, trigger short- and long-term positive emotions regardless of a person's sex and age [12], and can improve health [18].

2.2 Towards Living Visualizations

Since living plants affect people emotionally and can change people's behaviour [12, 18], researchers have used virtual plant metaphors to represent data. For example, Wang et al. [38] used a flower metaphor for visualizing Facebook data, and found that virtual representations of living entities could trigger insights. While some studies showed that virtual metaphors can motivate people to change their behaviour [4, 22], others argue that their impact on a person's motivation and behaviour remains unclear [9]. Overall, the HCI and Infovis communities have focused on virtual representations [3, 4, 9]; however, there is a growing interest in using physical metaphors to represent data (e.g., [16, 37]). Using physical metaphors to represent *personal* data have great potential to motivate people to gain awareness and change their behaviour [17, 19, 34].

From these two trends, it appears that both virtual and physical plant metaphors can improve awareness and lead to behaviour change. *Infotropism* [14] presents both a living and a robotic plant responding to the use of either a recycling or a trash container: the plants receive light from one side according to which container waste is put in. The plants then become visualizations of the proportion of trash and recyclables that are collected. Results from a study suggest a clear difference between the two types of plants: the robotic plant lost the interest of people after two days, while the living plant sustained their interest—with participants still caring for it after the two weeks of the study. They also found that with the living plant, some people changed their behaviour because they started caring for the plant and felt obligated to keep it alive, instead of a desire to recycle more.

We build on *Infotropism* to explore how people's attachment to *living visualizations* can be an engaging motivator for behaviour change. In contrast to *Infotropism*, which explored how the tilt of a plant can reflect *group* behaviour, where a group is responsible for the plant, we explore how the health of a plant can reflect *individual* behaviour, where an individual is responsible for the plant.

3. DESIGN CRITERIA

Looking over the literature, the increasing availability of fitness tracking devices has led to considerable research that assess how technology can help people in increasing their awareness of, and in improving, their activity level. We combine the strategies that have been proven successful for engaging people with their personal data: personable visualization, social context, cognitive behavioural strategies, and inciting emotions. Since people are usually emotionally attached to plants, we use this medium as a way of triggering emotions and engaging individuals with their activity data. From the literature, we identified design criteria that can have a positive effect on individuals' engagement, awareness, and behaviour change:

- **DC1** *Abstract representations* are more efficient than typical barchart-like visualizations for self-reflecting on personal data [5, 6, 22].
- **DC2** *Aesthetic, playful, and pleasurable representations* engage people with everyday data and trigger emotions [21, 31, 34].
- **DC3** *Goals that affect the representation* leverage successful cognitive behavioural strategies [2, 11, 23].
- **DC4** *Representations that can be shared* leverage the benefits of the social context on engagement [3, 33].
- **DC5** *Representations that trigger emotional commitment* favor both short-term and long-term engagement [22, 25, 27, 36].
- **DC6** *Non-virtual living representations* leverage both physical metaphors and living plant metaphors, as well as the sustainable interest for living things [14, 17–19, 34].

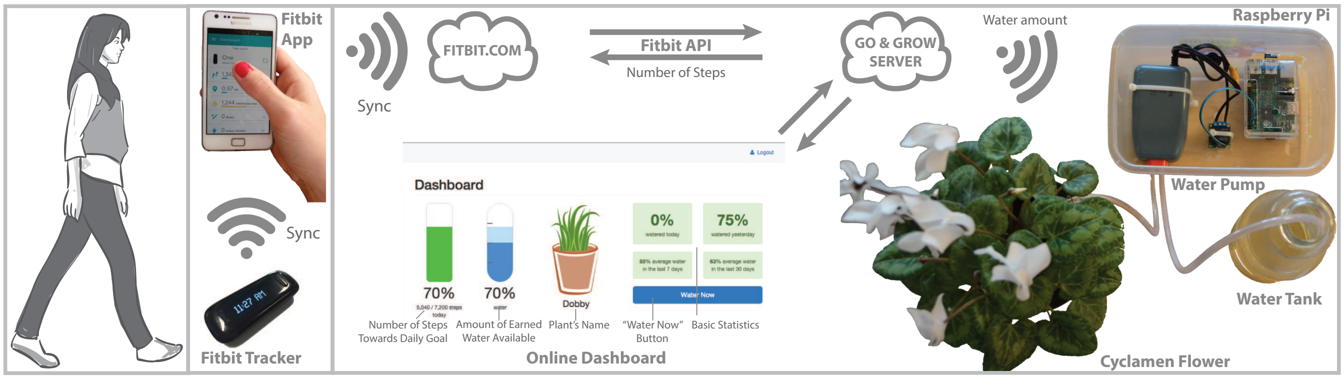

Figure 2: Overview of Go & Grow. The plant owner wears a Fitibit tracker. Once they sync their tracker with Fitbit.com, the Go & Grow server will access their activity data, and compute the amount of water earned corresponding to the number of steps walked. Every midnight, the server sends the earned water amount to the Raspberry Pi, which waters the Cyclamen plant accordingly. The owner can log on to an online dashboard to monitor their step and earned water levels, and to manually water the plant.

4. GO & GROW SYSTEM

The six design criteria informed our design of Go & Grow (see Figure 2), a system composed of a flowering plant, an irrigation system, and a step-count tracker. The amount of water given to a plant reflects the step count of the plant owner. Using a living plant to represent one's activity already satisfies four design criteria:

- **DC1**: The data is represented loosely (aspect, characteristics, health of the plant), not with precise numerical values.
- **DC2**: A plant is an aesthetically pleasing thing.
- **DC5**: People gain affection for plants and emotionally engage with them; they are less likely to let plants die than bar charts.
- **DC6**: A plant is a non-virtual living representation.

System Overview. Assume Anna is a person using a Fitbit tracker. Anna syncs her tracker with her online Fitbit account using the Fitbit application whenever she wants. Every midnight, the Go & Grow server accesses Anna's daily step count through the Fitbit API, and converts this step count into the amount of water to give to the plant. The server then sends this water amount to the wifi-connected irrigation system, which automatically waters the plant accordingly. Anna can see her daily progress, step count, and watering history in the online dashboard. Anna can also use the dashboard to water her plant in real time, based on her current number of steps.

Go & Grow Server. Once Anna syncs her Fitbit tracker, the Go & Grow server accesses her step data via the Fitbit API and converts her current step count to a percentage of completion towards her daily step goal. As her percentage of completion increases, Anna earns water. The earned water is represented as a percentage of the optimal daily dosage of water that the plant needs.

Everyday at midnight, the server sends the watering amount to the irrigation system and resets the step counter. However, the plant can only be watered in 25% increments (25%, 50%, 75% and 100%) in order to motivate people to achieve goals (**DC3**). For example, if Anna walked 8,500 steps and her goal is 10,000, she will earn 85% of water, but her plant will only get 75% of it's optimal daily dosage. The difference, 10%, will be *banked* (available for later use). If Anna achieves higher than 100% of her goal then the plant will get 100% of its water and the extra water will be banked.

Online Dashboard. Anna's online dashboard contains a green progress bar showing her progress towards her daily step goal and a blue bar showing how much water she has in stock. In the dashboard shown in Figure 2, the Anna has achieved 70% of her daily goal, but she can only use 50% of the water. Once Anna has earned at least 25% of water, she can click on the "Water Now" button to water her plant immediately, otherwise it will happen automatically at midnight. We implemented this functionality because: i) it gives the plant owners the opportunity to water their plant before midnight, as the pump makes some noise; and ii) plant owners can water their plant in real-time and observe that the system works as expected.

Irrigation System. The irrigation system consists of a Raspberry Pi (Version 2 Model B) and an aquarium water pump (3.5 gph Tom Aquarium Aqua Lifter Pump). The Wi-Fi enabled Raspberry Pi receives the amount of water from the server, and converts this amount to the time in seconds that the water pump must be turned on. The electronic components are fastened in a plastic box ($20 \times 10 \times 5$ cm). All the parts were bought from online stores and cost less than US $90, which makes the system easy to build and reproduce.

Cyclamen Plant. Although this may not look to be the most complicated part of the system, there are many variables to consider for choosing a plant. The main considerations are:

P1 Its aesthetics: the plant should be aesthetically pleasing.

P2 Its sensitiveness to water: the amount of water the plant receives should quickly impact its health and appearance.

P3 Its robustness to dryness: although the plant should be sensitive to water, it should be "forgiving" and be robust enough to not die immediately if not watered for a single day.

P4 Its environment requirements: the plant should be able to grow indoors, sometimes with little natural sunlight.

We considered many plants before choosing the Cyclamen. We considered tomato plants, which are sensitive to water and provide fruits, but are not particularly aesthetically pleasing, have a strong scent, and give fruits only when outdoor; mint, which grows fast, but triggers allergies; impatiens, which are aesthetically pleasing and sensitive to water, but inexplicably died during our tests. We finally chose Cyclamens, which satisfy **P1** to **P4**; we also did not encounter any issue with them. Cyclamens are valued for their flowers with upswept petals and vibrant colors (**P1**). Properly watered, they grow flowers at a rapid rate of 1–2 flowers per week, but their flowers will dry up quickly if they lack water (**P2**). A quick reapplication of water will cause the plants to revitalize (**P3**). Persistent dry soil, however, will impede healthy growth and will cause the plants to die. Cyclamens thrive in cooler temperatures and do not require direct sunlight, making them ideal for indoor settings (**P4**).

To determine the exact daily dosage of water Cyclamens need to grow healthily without being under or over watered, we consistently gave three cyclamen plants different amounts of water everyday for four weeks. We recorded observations such as flower color, leaf color, soil moisture, and number of flowers of each plant, and deduced the optimal daily water dosage to be 35 mL.

Figure 3: Go & Grow setup for the group participants.

5. GO & GROW QUALITATIVE STUDY

We ran a six-week study with ten participants using Go & Grow. We designed this study to explore living visualization for representing personal fitness data; and to examine people's reaction, motivation, and engagement with a personal living visualization.

5.1 Study Design

The study consisted of two phases, with each phase being followed by a recorded semi-structured interview.

Phase 1 consisted of a three-week period during which participants wore a Fitbit tracker. During this phase, we determined the average daily step count of each participant as a baseline that we later used to determine their daily goals. The first phase lasted three weeks to limit the novelty effect, because most people stop using their tracking device after three weeks [32]. After the first phase, we conducted short (15–30 min) entry interviews and collected participants' demographics, levels of activity, previous experiences with PI systems, and thoughts on the study. We asked participants to name their plant, both for privacy purposes and to initiate the emotional connection. The second phase began right after the entry interviews.

Phase 2 consisted of a three-week period using Go & Grow. We linked the Fitbit accounts of participants to their Go & Grow system. We set the daily step count goal of participants to be their average daily step count during Phase 1 plus 10% – so that participants would have to walk a bit more than usual. We introduced them to the online dashboard, and told them to sync their Fitbit at least once a day. At 11pm every day, participants who had not synced their Fitbit yet would receive an email reminding them to sync. At the end of Phase 2, we conducted 20-40 min semi-structured exit interviews containing both questionnaire questions and open questions.

Conditions: The only design criteria which is not enforced by Go & Grow is **DC4**: sharing the representation. Thus, we considered two types of participants. *Individuals* have their Go & Grow at home and do not interact with other participants of the study. *Group* participants are friends placed in a competitive setting, with the plants of all group participants being side-by-side in a shared workplace.

5.2 Participants

We recruited ten volunteers by email and word of mouth with no monetary compensation; this was to recruit people who were solely interested in tracking their steps and linking their data to a plant.

We recruited five individuals I1–5 (three male) aged 21–63 (mean 31). There were two students, one engineer, one teacher, and one manager. We recruited five group participants G1–5 (two male) aged 20–30 (mean 24) through a mailing list. All were students working in the same place, knew each other well, and interacted on a daily basis. We lent a Fitbit Zip to participants who did not own a Fitbit.

5.3 Go & Grow Deployment

The individuals placed the plant at a location of their choice at home. Three set up their plant in their kitchen, one in their bedroom

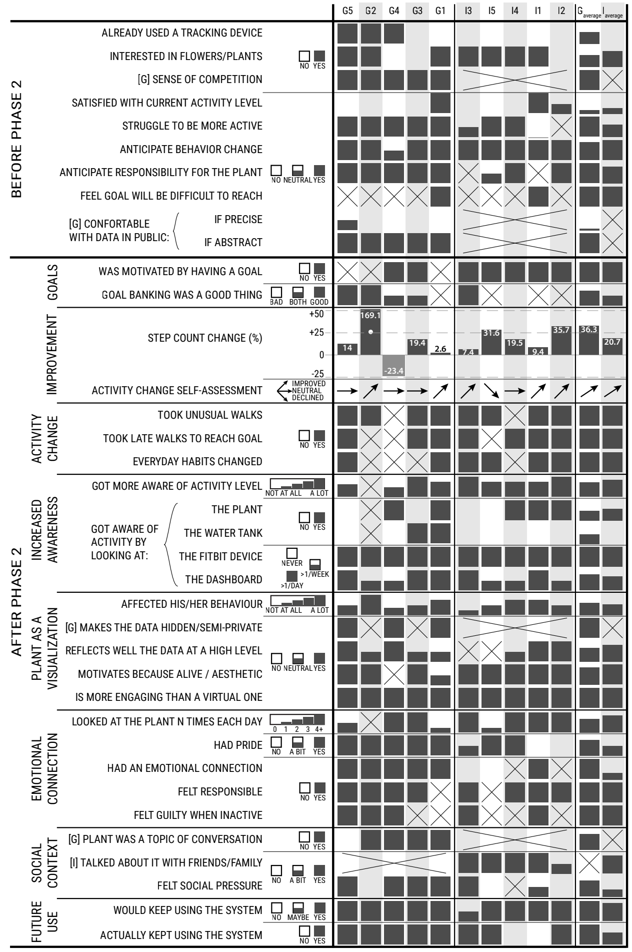

Figure 4: Topics and categories are in rows. [G] / [I] indicate that the row concerns only group participants / individuals. Participants are in columns; G[1-5] are group participants, I[1-5] individuals, $\{G, I\}_{average}$ averages. Cross indicate no data.

and one in their living room; all were near a window. For the group participants, we built a Go & Grow with one Raspberry Pi controlling five pumps, each connected to one plant. We set up this system in the semi-public lunch area, next to the main entrance of the workplace. Because plants were given names, participants did not know which plant belonged to whom. Since there were no windows nearby, we added a LED light fixture to illuminate the plants during day hours (see Figure 3).

6. RESULTS

We transcribed entry and exit interviews and complemented them with the numerical Likert scale answers. We analyzed the transcripts using open coding and affinity diagramming. We extracted 112 codes that we organized into 41 categories. We then grouped related categories into 8 emerging topics. We used Bertifier [29] to create Figure 4, presenting the summary of these results. The results from the entry interviews are summarized in the "Before Phase 2" section in Figure 4. We report the results from "After Phase 2" section in more detail below, according to the topics listed in Figure 4.

Goals. All seven participants who mentioned goals found it motivating to have a goal. This motivation was not always directly related to the plant, e.g., *"I was more obsessed with reaching the 100% than actually watering the plant" [I3].* Five participants enjoyed goal banking, e.g., *"it was nice to know that even if I was* *not getting all of my steps done today, my plant was still getting water" [G5].* However, I4 found it demotivating: *"if I had steps carry over then I didn't really care to do that many that day" [I4].*

Activity Change. All but G4 increased their average step count during Phase 2 compared to Phase 1. Five participants felt that they had improved their activity level during the past three weeks.

Behaviour Change. All but two participants mentioned taking unusual walks. These walks included: asking friends to go for a walk, e.g., *"I would tell my friends that we have to go for a walk because I need steps" [G1]*; taking a walk with their dog, e.g., *"If knew that I wasn't going to hit it for a day then I would go take [dog] for a walk" [I1]*; and extending walks, e.g., *"if I was at the end of a walk and I see that I still haven't reached my step goal yet by a little bit then I would extend the walk" [I3].* I2 also changed their behaviour for steps banking instead of for reaching the goal that day: *"I was going on vacation and I'm like oh well I should try get an extra 300% [of water] before this just in case I don't have access [to internet]" [I2].* Seven participants mentioned taking unusual walks late in the day to reach their goal, e.g., *"when I wasn't at my goal . . . I would pace back and forth down the hallway" [I1].*

Six found that their everyday habits had changed during the study. These changes include walking instead of being inactive, e.g., *"when I wasn't doing anything then I would go 'well I might as well go for a walk and get some steps in" [I2]*; changing meeting habits, e.g., *"just for both our sakes, we do walking meetings now" [I5]*; being more consistent, e.g., *"I feel I've developed a habit now so that's awesome" [I3]*; and changing the way of doing everyday things, e.g., *"If I was very close to my goal at night, make sure it will get a whole bunch of extra steps, like bouncing around. Or when you brush your teeth, you walk back and forth" [G5].*

Increased Awareness. Nine participants mentioned that they either became aware of their activity level, e.g., *"it created an awareness of how sedentary I am" [I5]*, or became more aware than before, e.g., *"It's not like I didn't know about those numbers before but now I feel . . . I should be on top of this a bit more." [G4].* Five participants said that they gained their activity awareness by looking at the plant; two by looking at the water; all by looking at the Fitbit multiple times a day and at the dashboard at least once a week.

Plant as a Visualization. Participants told us that the plant affected their behaviour by an average score of 3.3 (1: not at all; 5: a lot). Three group participants liked that the plant showed their data in a semi-private way, e.g., *"I could compare in a way but not really. I like how it was hidden" [G4].* Four participants mentioned that the plant represented their data at a high level, e.g., *"it was pretty responsive to being watered. . . . I think if you didn't see a big visual difference then it wouldn't have been as motivating" [I1].* Others were more neutral, e.g., *"it wasn't a very precise display" [G5].*

All but two mentioned the aesthetics and the living aspects of the plant as factors of motivation, e.g., *"It was kinda interesting to observe these flowers grow and bloom" [I3].* They all stated that they would not have felt the same with a virtual plant. The fact that the plant can die was the most frequent comment, e.g., *"a plant is a living organism. With a virtual plant, if it dies then you don't really care" [G3]*, and *"I feel like with a virtual plant I could always sign up for a new account . . . but with a real flower, I could kill it" [G4].*

Emotional Connection. All but one participant looked at their plant at least once a day. Eight felt pride, mentioning their plant to friends, e.g., *"I told [friend] about it . . . people thought it was cool" [G2]*, colleagues, e.g., *"I would start proudly talking about my plant" [G3]*, and family members, e.g., *"I showed it to my family. I showed a picture to a couple of people" [I4].* Others had secret pride, e.g., *"I have secret pride in my plant, it didn't die, that's really nice" [G5].* Six told us about their emotional connection with their plant, e.g., *"I developed a connection with the plant" [I1].* Some mentioned caring about the plant as if it was a pet, e.g., *"It was almost like . . . having a pet . . . you're taking care of it" [G3].* Two did not feel connected to the plant, e.g., *"I just didn't connect to the plant" [I5].*

All but two mentioned that they felt responsible to keep the plant alive and healthy, e.g., *"I didn't want it to die! I felt responsible" [I1].* Some talked about the long-term impact of this responsibility, e.g., *"I wasn't just thinking about it for the first week then forgetting about it. I was actively conscious . . . the entire time that my flower was dependent on my performance" [G3].*

Five mentioned guilt, e.g., *"If I didn't water it then I was feeling guilty" [I1]*, in several ways, including: because of their laziness, e.g., *"I'd felt kind of mean if it didn't get watered just because I didn't feel like walking" [G5]*; because they were not properly watering the plant, e.g., *"I still felt guilty when I didn't have at least 100% water every night" [I3]*; and when they received an automatic email, e.g., *"Every time I got an email . . . I would feel guilty" [G2].*

Social Context. Four group participants mentioned that the plants were a common point for discussion with colleagues, e.g., *"It was actually quite entertaining to . . . have a common point to talk about. We stood around the plants and discussed" [G3].* They all talked about their plant with family and friends, e.g., *"They [friends/family] still ask me about how my plant is doing every time they see me now, so it's a constant reminder to keep being active" [I3].*

Six participants felt social pressure during the study. Other people seeing their plants motivated group participants, e.g., *"I would have found it embarrassing if it weren't doing well, because people were paying attention to the plants" [G5]*; as well as having their plant being compared to other plants, e.g., *"I didn't want my plant to be the worst looking one" [G4].* Individuals mentioned positive social pressure coming from both family members and friends, e.g., *"if it started dying then [my family] would say something about it" [I3].*

Future Use. After three weeks of Phase 2, we offered the participants the opportunity to keep using the system. Eight decided to continue. The two who did not keep using it had reasons that interfered: I1 moved to a new city and could not take the plant with them and I4 lost the Fitbit tracker on the day of the exit interview.

7. DISCUSSION

Overall, participants increased their awareness of their activity level. During the three weeks of the study, participants also changed their habits towards a more active lifestyle. Based on our results, we discuss i) the impact of a living visualization, and ii) people's diversities as a factor when designing PI tools. We then introduce iii) the Goal Motivation Model, which is based on the degree of goal abstraction, captures different motivations, and supports diversity.

7.1 The Impact of a Living Visualization

Our results indicate that the emotional commitment to the living visualization is a key factor in motivating and engaging people towards improving their activity level. Participants connected emotionally to their plant – all mentioned that they did not want to let their plant die. Participants felt sadness, guilt, and pride towards their plant, and even compared the plant to a pet. The two participants who first told us that they did not feel connected to the plant later told us the opposite. I3 initially said *"I personally feel very indifferent about the plant"* but later expressed feelings of responsibility for the plant (*"I feel some kind of self-obligation every night to make sure that I've gotten enough steps"*); felt guilt (*"I felt kinda guilty if I didn't have enough water by the end of the day"*); and cared for the life of the plant (*"I would not have cared at all if the flower was virtual"*). I3 further said that the plant affected their behaviour: *"I would be about to eat . . . something fattening then I* *would see the plant and that would somehow make me feel guilty.”*; concluding *“I did care about [the plant] unconsciously”*.

This emotional commitment is probably due to the living visualizations being different from raw numbers, standard visualizations, and virtual metaphors, because they are *alive*. Although the plant is not the method by which people gain the most information about their activity level, it is the plant that the participants committed to the most. A living visualization gives *meaning* to an otherwise less meaningful goal of reaching an arbitrary numerical goal.

7.2 Considering the Facets of Diversity

People tracking or willing to track their activity data have diverse activity levels, goals, and motivation; they cannot be reduced to one single kind of stereotyped person. Our results highlight four types of diversity: 1) of activity levels, 2) of schedules, 3) of motivations and goals, and 4) of strategies for accomplishing goals.

1. Diversity of activity levels. People have an activity level ranging from nearly nothing to extremely high. However, standard tools do not consider this diversity. For example, Fitbit.com attributes the exact same goal of 10,000 daily steps to any new user.

Preset goals may be impossible to reach for someone with a low activity level. People with low activity levels in our study committed to the plant and did not care much about the actual numbers. These people still benefit from the social commitment since: i) the raw data is difficult to read because a living visualization is an abstract representation; and ii) both a professional athlete and a non-active person can compare their living visualizations because the goal is set to be relative to the activity of the person.

In contrast, people with high activity levels in our study tended to commit more to the numerical value than to the plant.

2. Diversity of schedules. When people have relatively consistent schedules, a daily goal is reasonable and favours consistency. Some of our participants had erratic schedules, unexpected events, deadlines, illnesses—a few of the many factors that can disturb daily activities. They may be discouraged quickly if their goal has to be reached every day. The living visualization and *goal banking* helped tackle this issue. First, the living visualization is a *forgiving* visualization. having less water for a couple of days altered the plant’s appearance slightly, but did not kill it. This results in minor punishments for someone who had been less active for a day or two. Second, *goal banking* can be capitalized. Goal banking consisted of capitalizing extra amounts of water. Participants used the stored water on days when they could not reach their goal.

3. Diversity of motivations and goals. Motivators included having a healthy plant, earning water, and achieving a numerical goal. In fact, participants were motivated by several of these aspects at once and pursued them with varying degrees of commitment. Even those with a low activity level, whose motivation mostly came from the plant and the social context, sometimes gained motivation for achieving the numerical goal. Inversely, those with a high activity level, mostly motivated by the numerical goal, also gained motivation through the social context, the water level, and the plant.

4. Diversity of strategies for accomplishing goals. Our results revealed three strategies that participants employed to ensure that their plant would receive the maximum amount of water every day:

- *Changing everyday habits* is a long-term behaviour change, that occurred for participants who preferred to change everyday habits rather than having erratic behaviours, typically by taking the stairs instead of the elevator and walking to work;
- *Planning for inactivity* is a mid-term behaviour change that occurred when participants anticipated a period of inactivity. They *banked* water by taking long walks the days before to ensure that their plant would get enough water everyday;

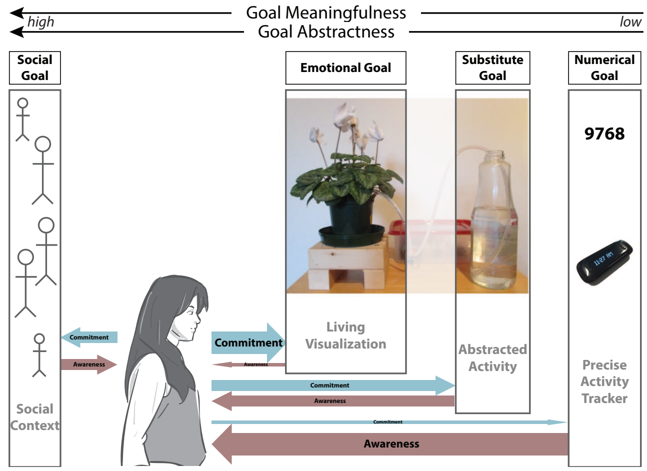

Figure 5: Goal Motivation Model. The four levels of goal abstraction—activity tracker, abstracted activity, living visualization, and social context—play a role in one’ awareness and behaviour change and have a commitment–awareness tradeoff.

- *Reacting under pressure* is a short-term behaviour change that occurred when participants realized that they would not reach their daily goal, typically by taking walks late at night.

Summary. Standard ways of visualizing personal activity data tend to be generic approaches which do not consider these facets of diversity. Our results show that these facets of diversity are all factors of engagement. Based on this observation, we introduce the Goal Motivation Model, which supports and even encourages considering the facets of diversity when designing PI tools.

7.3 Goal Motivation Model

From our results we derive the Goal Motivation Model, illustrated in Figure 5, that supports and encourages considering the facets of diversity. This model, based on the degree of abstractness of visualizations, results in a tradeoff between an person’s commitment to a goal and their awareness of their activity level. We describe the four levels of abstraction that surround a person in this model.

1. The precise activity tracker is the standard activity monitoring tool that provides a concrete *numerical goal*. Few people commit to this numerical goal, as evidenced by the quick drop off from activity trackers [32]. On the other hand, this level is the most powerful way for people to increase their awareness by providing them with precise numbers. In our study, even participants who already used an activity tracker and an online dashboard before the study became more aware of their activity level. Our interpretation is that people can increase their awareness of their activity level through activity trackers if they have an external motivation to look at their device every day—the plant in our study. This was echoed by our participants, e.g., *“Before, sometimes I wouldn’t even check it at all for a couple of days, but during the study I would check every day to make sure that my plant would get watered” [G4]*. In brief, this level provides the most precise information about the activity, but does not seem to engage people to commit to a goal.

2. The abstracted activity is the intermediate level between the precise activity tracker and the abstract living visualization. Water level does provide a slightly abstract visualization, similar to a bar chart. This level results in a *substitute goal* to the goal of reaching a number of steps. The key point is that the step count is not an end in itself, and neither is the earned amount of water. In this cascaded approach, the step count goal is a means by which people can collect water; the height of water goal is a means by which they can achieve their concrete goal—maintaining a living entity. Some people may focus on this activity measure instead of their step count, since the abstracted measure contributes more directly to their goal of keeping the plant alive. The abstracted activity shown by the water level also provides people with more awareness than the plant because the activity level is represented in a less abstract way. The substitute goal can also be used to *bank* abstracted activity.

3. The living visualization results in an *emotional goal*. People emotionally connect to the living visualization, and commit to the meaningful goal of keeping it healthy. They commit to achieving this goal because the visualization is a living entity whose life depends on their activity. They feel sad when the living entity looks unhealthy; proud when it looks healthy; and guilty when they are inactive. This variety of feelings does not occur when looking at numbers or bar charts. Although the living visualization results in a strong commitment towards the goal of keeping a living entity healthy, it does not provide people with much awareness of their activity level. This is due to the abstractness of the visualization, which in particular does not reflect short-term activity changes.

4. The social context surrounds the person with regards to the living visualization. This context can include other people tracking their fitness data in a competitive/comparative setting with friends, family, and colleagues. Social context creates positive pressure to maintain the living visualization's health, creating a *social goal*. This social goal relates to Fogg's [8] principles of competition, cooperation, and recognition, which bring intrinsic motivation. In this level, the social goal is meaningful: it consists of feeling proud of the health of the living visualization in front of other people. The entourage does not know the numerical value associated to the person's goal, and does not need to know how the living visualization is maintained. They just know that the health of the plant is somehow related to the level of activity of the person.

Goal Motivation Model and the facets of diversity. The model supports all facets of diversity discussed in section 7.2. It supports the diversity of activity levels, ranging from low to high, by using leveled goals with increasing abstractness. It supports the diversity of schedules, ranging from regular activity to erratic schedules, by 1) letting people commit to the *forgivable* living visualization; and by 2) providing them with a way to compensate inactive days with very active days. It supports the diversity of motivations and goals and the diversity of strategies for accomplishing goals, because it is flexible, which lets people decide the degree of abstractness they commit to and their strategy to reach their goal(s). This model relates to Fogg's [8] functional triad. Participants in our study were motivated by all three aspects of the functional triad (social aspect, tool and medium), however, with a commitment–awareness tradeoff illustrated in Figure 5 according to participants' diversity.

7.4 Limitations and Future Work

Our qualitative study revealed the existence of factors of engagement with personal activity data. The purpose of this study was to shed light on these factors and to deepen our understanding of what motivates people in tracking and self-reflecting on their personal activity data. Like many similar studies, the short duration of our study makes it difficult to claim that people changed their long-term behaviour. Instead, this work opens the space of using living visualizations for personal data. Our results will inform further research in this area, and we suggest different strategies to expand both the Go & Grow system and the Goal Motivation Model in the future.

Long-term response: While our study unveiled interesting results, a longer study would be able to explore the long-term effects of a living visualization on awareness and behaviour change. However, the fact that eight participants kept using the system after the end of the study is a positive indicator of enduring interest in the system.

Confounding factors: More studies are needed to fully understand the effect of individual factors on motivation and awareness.

Limits of goal banking: Goal banking allowed for forgiveness. However, having an excess of earned water discouraged some participants from being active. A limit could be placed on the amount of water stored, or water accumulation could be prevented by adjusting the daily goal based on recent performance. Gradually increasing their step goal would actively challenge those who have increased their activity level. Similarly, gradually decreasing the step goal of those who have been struggling could provide encouragement.

Beyond steps and water: Other controls could be applied to other factors that influence a plant's growth, e.g., varying amounts of light and adding fertilizer. Similarly, step count does not fully represent one's activity level. Other metrics such as heart rate, calories burnt and floors climbed, could be used to control different parameters that affect plant growth, e.g., lighting according to floors climbed, adding fertilizer according to calories burnt, etc.

Timeliness of change: The plant gave little short term feedback of activity level. Short term feedback could be increased by adding dye to the water, which travels up the plant and tints the petals. A plant that receives more water would be more vibrantly coloured. Making the living visualization less abstract in the Goal Motivation Model would affect the tradeoff between the timeliness of change of the plant and the abstractness of the visualization. Abstractness offers forgiveness and privacy—two important factors of engagement.

Ethical issues: Living visualizations are not constrained to plants. Some participants made a parallel between taking care of a plant and taking care of a pet, which raises some important ethical issues.

8. CONCLUSIONS

We explored living visualizations as a tool to engage individuals to gain awareness of their activity level and motivate them to be more active. We designed, implemented, and evaluated Go & Grow as a proof of concept of living visualizations. By linking individuals' step count to the amount of water that their plant receives, we revealed unexplored aspects of personal activity tracking. Notably, we found that individuals emotionally commit to the goal of keeping the living visualization alive, regardless of their activity level. Living visualizations differ from existing tools and virtual metaphors, because they trigger feelings such as pride, sadness and guilt.

By analyzing the results from our study, we distilled four goals with different levels of abstractness that individuals can commit to, based on which we built the Goal Motivation Model. This model considers the diversity of individuals, thus supports and encourages diverse strategies for accomplishing goals. Because it encompasses four levels of goal abstractness, it can be applied beyond activity tracking, paving the way for designing technologies that will help individuals commit to personal goals in their everyday life.

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