A System for Triggering Reflection on Physical Activity using Conversational Mini-Dialogues

ABSTRACT

Despite reflection being identified as a key component of behavior change, most existing tools do not explicitly design for it, carrying an implicit assumption that providing access to self-tracking data is enough to trigger reflection. In this work we design a system for reflection around physical activity. Through a set of workshops, we generated a corpus of 275 reflective questions. We then combine these questions into a set of 25 reflective mini-dialogues. We deliver our mini-dialogues through MMS. 33 active users of fitness trackers used our system in a 2-week field deployment. Results suggest that the mini-dialogues were successful in triggering reflection and that this reflection led to increases in motivation, empowerment, and adoption of new behaviors. Encouragingly, 16 participants elected to use the system for two additional weeks without compensation. We present implications for the design of technology-supported dialog system for reflection.

Author Keywords

Conversational design; reflection; behavior change; physical activity; reflective dialogues

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

INTRODUCTION

Reflection has been identified as a key element of successful health behavior change [29,32] and is an important step in stage-based models of personal informatics [14,28]. Through the process of reflection, users can increase their self-knowledge [6], formulate realistic behavior change goals [27], and increase self-control while promoting positive behaviors [29]. Reflection has been considered an impetus that moves the individual from examinations of his or her data to action [5].

Despite such importance, personal informatics models

reveal little about how reflection can be triggered [6]. Consequently technology has struggled to successfully support refection in practice [16][40]. As noted in [6] *"prior work carries an implicit assumption that by providing access to data that has been 'prepared, combined, and transformed' for the purpose of reflection, reflection will occur."* Indeed, the two main means of facilitating reflection in behavior change and personal informatics rely on visualizations of self-tracking data, such as Fish'n'Steps [30], UbiFitGarden [13] for physical activity; Affect Aura [33] for affective states and LifelogExplorer [24] for stress. The other approach relies on journaling [38], such as SleepTight [12] for sleep and Affective Diary [31] for manual journaling of emotions.

In contrast, several personal counseling techniques, such as motivational interviewing [43] and commercial behavior change programs (e.g., Weight Watchers [20]), use interviewing techniques to effectively trigger reflection. Also personal coaches *"repeatedly ask questions to get at hidden motivations"* and that asking reflective questions can motivate people to use a service by enabling them to articulate underlying needs and goals [27]. Such strategy can elicit contemplative [21] and metacognitive [15] thinking encouraging people to think about their needs and wants beyond their first answers that come to mind.

In this work, we explore the use of conversational mini-dialogues for triggering reflection on physical activity. Despite the popularity of commercial fitness tracking tools such as Fitbit and Garmin, many of these tools do not currently explicitly support reflection [12]. Thus, to explore how reflection might be integrated into these tools, we designed and deployed a conversational system (see Figure 1) that delivers reflective prompts in 3 categories of reflection based on learning theory: *Noticing*, *Understanding* and *Future Actions* [35]. In a series of workshops with 12 active Fitbit users, a set of 275 prompts were generated. These 275 prompts were combined to form 25 mini-dialogues used by our system, each consisting of an initial question and static or dynamic follow-up question. Our system delivers these mini-dialogues along with graphs of the user's data over MMS to the user's mobile device.

Using a 2-week long field study in which 33 Fitbit users received one mini-dialogue a day, we demonstrate that our system is able to successfully trigger reflection that in turn can lead to an increase in mindfulness, motivation, adoption of new behaviors around physical activity, and

empowerment through increased understanding of barriers and formulation of concrete action plans. Further, we identify how different aspects of our design deepen reflection by making it more actionable, personal and accountable. We show that follow-up prompts are most useful when they dynamically build on top of user responses. A strong indication of success, 16 participants elected to continue using the system for two additional weeks without compensation.

This work makes the following contributions: 1) We adopt a structured reflection model from learning theory to inform the design of conversational mini-dialogues for proactively triggering reflection on physical activity; 2) We present a system demonstrating that our approach is feasible, beneficial, and appreciated by the users; 3) We propose a process of generating diverse reflective questions and offer a categorization that can be used to inform future design in conversational reflection.

RELATED WORK

A stage-based model of personal informatics states that *"collection and reflection are the core aspects of every personal informatics system"* [28]. Yet, a gap exists in understanding how the process of reflection can be supported through technology [42]. Indeed, designing for reflection is still in its infancy [16][5]. Furthermore, existing work does not always define reflection [6], and even journaling, one of the prominent methods used to trigger reflection, is reported to be largely unexplored in this respect [38]. As a result, much HCI research that attempts to inform design for reflection is based on structured reflection models from learning theory where such models and theories are more mature [16]. Thus far, such works have shown how learning models can be adapted to HCI for analyzing reflection [16], reviewing it [6], or designing for it on a conceptual level [40]. Critically, little work has been done on supporting structured reflection in deployed behavior-change systems. Our work aims to fill this gap.

Structured Reflection Models

A number of theoretical works on reflection have been developed in learning sciences. Some of them focus on exploring the nature of reflection itself [10] or the place of reflection in different professions [41][35] without necessarily focusing specifically on how reflection could be triggered. From a design perspective, particularly valuable are models for structuring reflection [16]. Such models see reflection as a process with stages or levels. Kolb's learning cycle defines 4 stages [25], Gibb's reflective cycle proposes 6 stages [18], and both Moon's levels of learning [35] and Bain's 5Rs framework [4] suggest 5 stages (or levels) of reflection. Fleck and Fitzpatrick have proposed an adaptation of these models to HCI, defining 5 levels of reflection [16]. These models, however, were developed to analyze reflection post factum and may be too fine-grained for direct use in design. Conveniently, Atkins and Murphy

Figure 1. Examples of actual user exchanges with our system's mini-dialogues, from the deployment study.

[3] in their review of literature on reflection, identified three commonly shared stages: *awareness of uncomfortable feeling and thought*, *critical analysis*, and *development of new perspective*. Our approach aligns with the three stages from Atkins and Murphy, renaming them for simplicity into: *Noticing*, *Understanding* and *Future actions*.

Stage 1 – Noticing

This stage focuses on building awareness of events and behavior patterns, but without an explicit attempt at explaining or understanding reasons. The stage is aligned with Fleck and Fitzpatrick's *revisiting* and *reflective description* levels where description of an even is provided without further elaboration, explanation or interpretation.

Stage 2 – Understanding

This stage focuses on analysis of the situation from different perspectives, formulating explanations and observations about the reasons for the things noticed. The stage is aligned with Fleck and Fitzpatrick's *dialogic reflection* level where cycles of interpreting and questioning as well consideration of different explanations, hypotheses, and viewpoints are taking place.

Stage 3 – Future actions

In this stage, Understanding leads to development of a new perspective, learning a lesson, or gaining new insights for the future. In terms of Fleck and Fitzpatrick's levels, this step aligns with levels of *transformative reflection* and *critical reflection* where past events are revisited with intent to re-organize them and do something differently in the future. Personal assumptions are challenged, leading to change in practice and understanding. Here also wider implications of actions are taken into consideration.

Conversational Approach towards Reflection

As pointed out *in* [6], many current approaches in personal informatics support reflection as an activity of *"looking at*

lists of collected personal information or exploring or interacting with information visualization". Yet human-coaches of behavior change take much more active approaches, asking reflective questions that can help people articulate their underlying needs and goals and increase their motivation [27]. In one example, people who were asked to think about why they eat snacks before making a choice were more likely to choose healthy options [17]. In fact, research has shown that asking people their reasons for doing an activity triggers underlying motivations and leads to focus on higher-level goals [11,44]. Specifically asking 'why' questions twice has been shown to be effective [29] as well as asking people to take more time to think about the question and to write longer answers [32].

The paradigm of computers as social actors [36] argues that people will apply social rules to a computer. This suggests that successful human counseling techniques might also work effectively in computer based delivery. Indeed an accumulated body of research has demonstrated the efficacy of human counseling inspired computer-based interventions [7]. In fact some research suggests that in computer-based counseling services, without dialogues, people may be less inclined to comply and may provide only superficial answers to questions [27]. Consequently, in virtual agent related research, it has been a goal to construct an engaging, long-term relationship with the user [9].

A comprehensive review by Bickmore and Giorgino on work in health education and behavior change dialogue systems [8] has revealed application domain spanning exercise, diet, smoking cessation promotion, medication adherence and chronic diseased management education and promotions. Specifically for physical activity most common approaches relied on building persuasive dialogues, oftentimes based on fixed dialogue structures [1]. Reflection was not the main focus, and when used related to reflective listening from motivational interviewing, where the approach for reflection is to provide a "tell me more" prompt or simply restate what the user said [37], Furthermore, most of the approaches target infrequent counseling session based interactions. Revisiting such dialogue again provides the same fixed interaction. This could be a problem in personal informatics when new data is collected daily and frequent, but short, reflective sessions could be appropriate. In fact, in the FitTrack study [9], several subjects mentioned that repetitiveness in the system's dialog content was responsible for their losing motivation to continue working with the system and following recommendations. In general although counseling interventions delivered by computer have been found effective, high drop-out rates due to low user engagement during interaction limit their long-term adoption and potential impact [39]

Reflection in personal informatics offers a unique challenge for computer-based dialogue system as it relies on open user responses, is relatively frequent and requires novel perspectives to engage users each time over long-term.

DESIGNING FOR REFLECTION
To understand the potential of a conversational system for triggering reflection, we designed and implemented a custom system, focusing on the domain of physical activity and fitness. Users interacted with our system through a series of mini-dialogues that were generated from a set of workshops with active fitness tracker users, described next.

Procedure
We recruited participants through social media posts and mailing lists. Prior to the workshop, participants were asked to share their daily, weekly, and long-term behavior change goals, as well as take screenshots of their self-tracking data from the previous 2 weeks, including measures of steps, calories, distance traveled, floors, resting heart rate and sleep, if available.

We started each session with a semi-structured discussion around reflection, in which we asked 5 questions: *1) What reflection on behavior change have you engaged in? 2) What is the goal of reflection for you? 3) How often/when do you usually reflect? 4) Where do you access your self-tracking data? 5) What are the main challenges in reflecting for you?* For each question, participants wrote their responses on post-its, shared each response with the group, and provided clarification when needed.

After the discussion, each participant was given a paper form with instructions to write at least two reflective questions for each of the 3 reflective categories of *Noticing*, *Understanding*, and *Future Actions*. This was repeated 3 times, with different source material in order to trigger diverse questions at different levels of specificity:

1. Participant's own behavior change goals
2. Participant's goals + data screenshots
3. Someone else's goals + data screenshots

Each session lasted an hour on average.

Participants
We held 4 workshops with 12 participants (8 female, 4 male), with an average age of 27.3 (SD=2.9). Three were undergraduate students, 6 graduate students, 3 working as developers and one as a fitness coach. Seven of the participants used Fitbit exclusively, 3 in combination with other tools and 2 used other apps exclusively.

Insight from Goals and Discussions around Reflection
Here, we discuss key insights from the workshops and present examples based on notes shared by the participants.

Current reflection: limited and notice centric
7 of 12 participants engaged in reflection on behavior change by mostly reviewing past data and trying to gain self-awareness: *"Comparing / scrolling back" (P7), "Mindfulness about behaviors we don't usually put much thought into" (P6).* Few also reflected to check if they were

	General/ Context (n=27)	Goals (n=50)	Tracking (n=29)	Observations/ Patterns (n=69)	Motivations (n=20)	Plans/ Scheduling (n=24)
Noticing (n=76)	What are you doing to be more active?	How many days did you meet your goal?	How many nutrition foods did you eat that day/week?	On what days do you walk more?	Did you notice any especially motivating moments this week?	What were the discrepancies between your plans and actual activities?
Understanding (n=116)	What are the top 3 reasons you're stationary?	Why do you only hit your goal on certain days?	What actions lead you to logging your food?	What happened during peaks/low points during your week?	Why were you sometimes unmotivated this week?	Why did you skip some part of your plan this week?
Future Actions (n=83)	What events could affect your activity next week?	Should you reevaluate your goals?	What other metrics do you want to track?	How can you avoid low activity days next week?	How can you encourage yourself to exercise regularly?	How can you set yourself up to have a day similar to successful days before?

Table 1. Examples of reflective questions generated during the workshop sessions. Questions are grouped by the main prompted categories (rows) and categories identified in through affinity diagraming (columns). Only the 6 most frequent categories are shown. The five white cells represents intersections for which the workshop participants generated no questions. For creating diverse and novel questions, we suggested questions for these intersections ourselves.

meeting their goals: *"Am I meeting my goal?" (P4)*, or to gain motivation and a sense of achievement: *"Get additional motivation"(P1), "See my own achievement" (P10)*. In terms of frequency, 7 participants indicated they reflect on their data on a daily basis, but mostly on data from the current day only: *"Focus on data at the moment, from current day at most" (P2)*. Further, 4 reflected only before or after a specific event: *"After a big workout day, to enjoy achievement" (P7)*.

When asked about the ultimate goal of their reflection, 6 considered it to be to provide motivation and to push towards goal achievement: *"Go out to reach daily goal - walk (push towards doing things)" (P2)*. Further, 4 considered it to be a self-checking mechanism or a way to gain mental satisfaction: *"Looking at steps helps my self-image when I know I am active" (P6)*. Three considered the goal to be learning connections between actions and outcomes and only 1 considered increased awareness to be a goal on its own.

Reflection boring, repetitive and easy to forget
3 of the participants considered reflection to be a boring and repetitive activity: *"Similar questions, a little repetitive" (P7), "I get bored with the same goals and stop using the device" (P1)*. Further, three participants indicated that sometimes they simply forget to look at their data or even to wear their device and would appreciate having engaging triggers that help them reflect: *"Having triggers to reflect in an engaging way" (P3), "trigger to think about my data in useful moments" (P9)*

Five participants indicated that the metrics provided by fitness trackers do not necessarily help them understand the impact of activities or decide what to do next: *"Need more useful metric than steps/calories" (P3). "Not necessarily clear what to do with it" (P7)*. Eight participants suggested the need for better uses of tracked data, including

encouraging relevant and insightful comparisons: *"Use comparative analysis for recommendations to set targets" (P2)*, and helping to discover trends and to understand their data better: *"make me understand my data better, specifically what actions work" (P1)*. Seven participants indicated interest in receiving suggestions on what to pay attention to, which activities to try, and generally gaining a new perspective on their data: *"getting different perspective, looking at the data in a new way" (P4)*

Self-tracking data can be demotivating
Few participants reported that they sometimes purposefully avoid looking at their data, and that further reflection can be demotivating: *"I sometimes avoid it because I am worried about what I will see in the data" (P10)*

Reflective Question Generation
A key goal of the workshops was to generate a set of reflective questions that could be used by a system to trigger reflection. Workshop participants generated a total of 275 questions in 3 categories we prompted for: Noticing (n=76), Understanding (n=116) and Future actions (n=83). Following the generation, we found the questions within one category were not all the same and, in fact, could be further categorized to separate similar and dissimilar question. We decided to perform this categorization to be able to later select the most diverse representatives for each discovered category. To do that, we performed affinity diagraming among 3 researchers to categorize the questions. The most frequent categories are presented in Table 1. These categories represented different specific aspects of behavior change the participant reflected on.

A CONVERSATIONAL SYSTEM FOR REFLECTION
Based on the outcomes of the workshops, we set out to design a system with the following three goals: 1) Support deeper reflection on self-tracking data, 2) Provide engaging, novel and diverse triggers to reflect, and 3) Allow users to interact with our system on their personal mobile devices.

#	Reflection-level progression	Mini-Dialogue features	Initial question	User response category	Follow-up question
1	Noticing → Understanding	Data Graph Goal reference Tailored follow-up	*Referring to your goal of [goal]. How many days did you meet that goal?*	Met the goal	*What did you do on days when you met that daily goal?*
				Did not meet the goal	*Why didn't you meet your goal on any day?*
				Other	*Why did you set such a goal for yourself?*
2	Understanding → Future Actions	Static follow-up	*Why is physical activity important for you?*	Any	*What steps can you take to be more active?*
3	Future Actions → Understanding	Data Graph Tailored follow-up	*Take a look at your graph. Do you think you can be more active?*	Yes I can	*What small changes (daily repeatable) can you make to be more active?*
				No I can't	*What barriers prevent you from being more active?*
				Other	*Do you want to be more physically active?*

Table 2. Three sample mini-dialogues used in our system. Reflection-level progression describes the matching of the initial and follow-up questions to the intended reflection levels. For the User-Response category, the free-text user response is categories using ML/NLP techniques.

Figure 1 shows two examples of the system in action. Based on questions obtained from our workshop sessions, we formulated 25 mini-dialogues. As most of the questions from the workshops were formulated with a specific focus on the particular workshop participant they were addressed to (e.g., *"Why do you walk significantly less on Saturdays (and weekends) in general?"*), our first step was to make these questions more general (e.g., *"Why do you walk less on some days?"*). To explicitly support the process of reflection described in past work, we balanced the set of questions focused on noticing, understanding and future actions. To increase the diversity of our dialogues, we selected questions to maximize the number of unique behavior change aspects (categories) they belonged to.

Supporting Deeper Reflection through Follow-Ups
To support deeper reflection, we used follow-up questions. Based on the research on structured reflection models, such mini-dialogues also have an opportunity to direct the reflection towards deeper levels. To do this, we created follow-up questions to most of the initial reflection prompts. We followed the progression of the reflective process: questions about awareness would be followed by questions about understanding, whereas questions about understanding would be followed by questions about future actions. In contrast to the initial question where a reminder is sent if the user has not responded, to minimize interruptions, no reminders are sent after the follow-up question if the user choses not to respond. 23 mini-dialogues feature a follow-up question. The follow-up is asked only after the user provides a response to the initial question. Ten of these have the same follow-up question regardless of what the user writes in their initial response. However, the remaining 13 mini-dialogues feature a dynamically tailored follow-up question (see dialogues 1 and 3 in Table 2). In such dialogues, a different follow-up question is delivered depending on the user's initial response. As users can provide free-text responses, tailoring the follow-up was based on NLP/ML model we trained using the online Language Understanding Intelligent Service (LUIS)[1]. There is always a possibility that users provide a response that we did not anticipate. For that reason, we created an "Other" category for each dialogue that captured all user responses that didn't match any other category.

Providing Engaging and Diverse Triggers to Reflect
To make the reflective dialogues engaging, we personalized the experience by introducing questions that were *dynamically referencing user personal behavior change goals* (see #1 in Table 2). 5 mini-dialogues referenced users' behavior change goals. These mini-dialogues were

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[1] https://www.luis.ai/

template based and automatically used the user reported daily, weekly or long-term goal. Each dialogue also addressed user by name and employed a friendly conversational tone following indications from [23]

Furthermore, in order to make the reflection focused and personally relevant, 17 mini-dialogues were delivered with a graph showing user's physical activity metrics (15 plotting steps, one calories burned and one sleep). 14 of these graphs showed a week worth of data, 3 showed a comparison of two weeks of steps (see Figure 2). The ones used in the core 2 weeks of study showed only steps data.

System implementation
In order to allow a broad set of users to interact with our system using their own mobile devices, we chose to implement our dialogs as SMS/MMS exchanges. This allowed reaching users regardless of their choice of mobile OS. We implemented our system as a PHP server using a Twilio API for managing the SMS/MMS exchanges. To generate graphs for users' physical activity, we used FitBit API to download latest synchronized user data periodically throughout the day. This required users to grant access to their Fitbit accounts at the beginning of the study.

In order to tailor the follow-up questions to users' free-text replies, we used Microsoft's online LUIS platform accessible through REST calls. We trained the recognition of different response intents based on potential user responses generated by ourselves and through internal testing and prototyping of the system.

FIELD STUDY
To evaluate our conversational mini-dialogues system's ability to trigger reflection and encourage participation, we conducted a 2-week field study. The study was approved by our university's Institutional Review Board.

Method
At the start of the study, participants provided our system with access to their Fitbit data. Participants completed a survey, in which they shared their daily, weekly, and long-term behavior change goals and indicated the time frame during which they would like to receive the reflective mini-dialogues. They then completed a set of scales related to awareness and reflection (detailed in the Measures section), followed by demographics.

During the study, participants received one mini-dialogue per day over the course of 2 weeks, delivered to their mobile phones via SMS/MMS. Mini-dialogues were selected at random and delivered at a random time each day (within the time frames specified by the participant). If the participant did not respond to the initial question within 30 minutes, they received a reminder. Only one reminder was sent per dialogue. Follow-up questions were sent after an initial response was received. After responding participants received a thank you message. At the end of the 2 weeks, participants completed a post-study survey, responding again to the same scales. Participants also indicated

willingness to take part in a phone interview. Finally, participants were allowed to choose to use the system for 2 more weeks without additional compensation (we clarified that their decision would not affect their $30 payment).

Measures
To assess the impact and success of our system, we look at measures of engagement, continued participation, and any changes in the self-reported scales. We then examine participants' attitudes and descriptions that emerged from the interviews.

Participants' interaction with the system was logged and analyzed. This includes the number of dialogues responded to, the time until a response was made (and whether a reminder was used), as well as the length and content of responses. These measures are used to assess engagement with the system. Participants' daily steps were recorded from their Fitbit data, as well as steps they took the week before the study. We also asked participants to complete a set of scales before and after the study. These included a scale of health awareness adapted for physical activity using a 9-item questionnaire from [19], level of reflection around self-tracking using an adaptation of Kember's 12-item questionnaire with 4 constructs of habitual action, understanding, reflection and critical reflection from [22] and general mindfulness using a 13-item questionnaire from [45]. Changes in pre and post scale ratings were analyzed using paired t-tests.

To gain a deeper understanding of participants' interaction with the system, semi-structured interviews were conducted following the study. Each interview lasted 40 minutes on average and was audio-recorded. The interviews explored the following aspects: 1) general experience with a system, 2) things learned about behavior and tracking, 3) experience of reflection, 4) perception of mini-dialogues, 5) value of every-day questions, 6) feeling of engagement, 7) impact on behavior change goals, 8) impact on motivation/self-efficacy, and 9) reasons for continuing/not-continuing for 2 additional weeks. Interviews were first transcribed and quotes related to each of the categories covered in the interview were extracted following a closed, selective coding approach. Quotes were then regrouped by iteratively subdividing or combining across the initial categories to reveal a set of stable underlying themes. This process required several iterations and followed a general procedure for analysis of qualitative data described in [26].

Participants
Participants were recruited through social media (17 fitness related Facebook groups, 30 fitness Twitter tags and Reddit) as well as mailing lists and physical flyers. Participants were U.S. based, used Fitbit for at least 2 week, willing to provide access to their Fitbit data, and willing to receive up to 4 SMS/MMS messages per day on their mobile phone for a period of 2 weeks.

Participants were rewarded $30 for the study and an additional $20 for the interview. A total of 33 active Fitbit users participated in our study (29 female, 4 male) between ages of 21 and 60 (M=36.5, SD=11.2). 55% reported having a college degree or being enrolled in college, and a further 27% indicated having a graduate degree. Participants logged 10,133 steps per day on average (SD=6,521, range: 1768 - 36757) during the week before the study. Five participants logged fewer than 5k and 13 more than 10k steps per day. Furthermore, our participants rated themselves highly on scale of awareness (M=5.63, SD=0.93). While this is a positive characteristic of our participants, it also implies that finding increases in this scale is unlikely - a known outcome or limitation of bounded scales (numerically, participants who rate themselves 7 have no room to improve). 19 of the 33 participants were interviewed after the study.

RESULTS

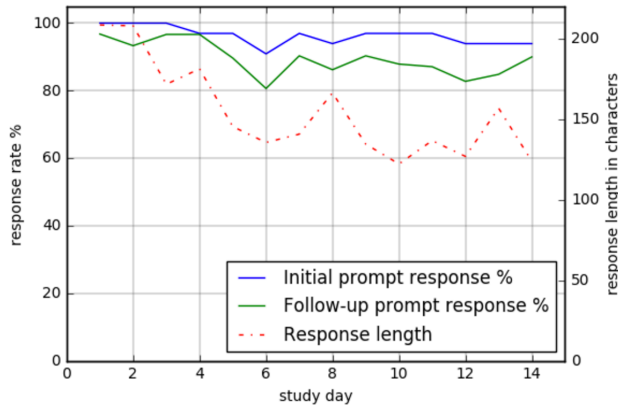### Engagement with the System

Figure 2. Response rates to initial and follow-up questions as well as average response length in characters for 14 days of core study.

We first examine how participants used the system, focusing on the two weeks completed by all participants. During the course of the two weeks, our system sent a total of 462 prompts and 429 follow-ups, receiving 829 responses from participants. Participants responded to 96% of all initial questions and to 90% of the follow-up questions. While 11 participants responded to all questions, the lowest response rate for a participant was 23% and 64% for initial and follow-up questions respectively. Overall response rate stayed fairly consistent, indicating generally high engagement throughout the study. However, Figure 2 shows a decline in the length of response as the study progressed, decreasing from an average of 170.1 characters in the first week (SD=31.8) to 138.1 characters in the second week (SD=17.0). Participants took 50 minutes on average to respond to the first question and 13 minutes to respond to follow-up. Reminders were sent in 39% of cases.

In our analysis of user responses to the reflective mini-dialogues, we found that the dialogues were in fact successful in triggering awareness related to goal accomplishment, self-tracking data, and trends in behavior: *"I like to be active on the weekend and it catches up to me on Mondays so I take it easy, then it back to working out on Tuesdays and Wed."*. Mini-dialogues also appear to have helped participants to better understand their behaviors. They were able to draw connections between the step count and their context, such as weather and external events: *"The weather helped! Also circumstances -- I had meetings and events that I needed to walk to"*. And relate physical activity to mental states and lifestyle routines: *"I've been really stressed at work lately, which has made me less active, since I need to finish projects"*.

Additionally, participants reflected on multiple higher-level aspects such as the value of physical activity, the meaning of a healthy lifestyle and the value of comparing oneself to others: *"My best friend is a doctor and has 3 kids and exercises way more than I do. (...) So sometimes I feel lazy when I compare myself to a friend, but most of the time I realize this is my life and comparing myself to someone else is not a mentally healthy practice, so I give myself grace."* They often reflected on things that worked for them: *"Jogging helps me towards the goal of jogging a half marathon. Writing out my training plan on a calendar has been helpful."* and also about what they could possibly change: *"Short runs before or after work. I enjoy running but I don't often make the time anymore. Standing at my desk more. Taking breaks not just at lunch. Getting a dog."*

Aside from reflection, the dialogues provided additional benefits. For example, the prompts enabled users to vent: *"Annoyed that some of them are thin without even putting in that much effort. Sometimes annoyed that I can try so hard for less rewards"*. The mini-dialogues often served as reminders: *"Today is my first day back at work so I have not done it yet - will do it if I go to a diff floor"*.

Pre and Post Quantitative Measures
Looking at the self-reported ratings, we find a significant difference in Habitual Action (HA) for pre (M=3.16, SD=1.06) to post (M=3.53, SD=0.89) study measurements; t_{32}=-2.0386, p<0.05. We also find a weakly significant increase in Understanding (U) from pre (M=3.60, SD=0.98) to post (M=3.92, SD=0.84); t_{32}=-1.8994, p=0.07. Other differences were not significant.

Considering these differences, HA is defined as an activity learned in the past that through frequent use becomes something performed habitually [22]. In their questions, reflection co-occurred with the activity ("When I am working on some activities, I can do them without thinking about what I am doing"). One potential explanation for the increase in ratings of tracking as Habitual Action in our analysis is that our system enabled a decoupling of the activity (here, physical activity) from reflecting on the activity (here, taking place when engaging with the system). Indeed, participants' responses to mini-dialogues,

	Pre study	**Post study**
Habitual action (HA)	3.16	3.53*
Understanding (U)	3.60	3.92†
Reflection (R)	3.54	3.64
Critical Reflection (CR)	3.60	3.85
Mindfulness (M)	2.52	2.63

Significance: * $p<0.05$, † $p<0.1$

Table 3. Summary of pre and post study measures. We report only the metrics that did not suffer from ceiling effect.

discussed above, reveal that the system successfully prompted reflective thinking.

Continued Use as Success Indicator
One surprising and highly encouraging indicator of our system's viability for ongoing use is the large number of participants who elected to continue to use the system beyond the study's 2-week period. In fact, 16 out of the 33 participants elected to continue using the system for 2 additional week without reward. Furthermore, these participants continued to engage with the system at a high rate, responding to 83% of the initial questions and 76% of the follow-up questions during the additional 2 weeks. Average response length during the additional 2 weeks was 98.4 characters (SD=74.9). While the system serves, in part, as a reminder, the sustained high engagement suggests that participants found additional value in the system's use for triggering reflection. We now turn to participants' own description of their experiences using the system.

Analysis of the Interviews

Types of reflection triggered
The 19 interviews confirmed and expanded the results of the analysis of user responses to the mini-dialogues in showing that the system was successful in triggering reflection on past activity patterns, on possible future actions and on new, previously not considered aspects.

Increased awareness: 10 of the interviewees reported that the system increased their awareness of past physical activity. The system specifically helped them realize how much they were recently doing and notice repeatable patterns in their own physical activity: *"It made me more aware that I am doing more steps when I'm at home and on the weekends. It just made me much more aware of how little and how much I'm doing on certain days." (P8).* 4 interviewees claimed the system helped them think about how they are currently planning and allocating time to their activities: *"Got me to go back through my data and my calendar, and really stop and spend time thinking about, 'Okay, am I really prioritizing this or not?'" (P14).* Also, 4 participants said it led to them thinking about the relationship between activities, data, and the health outcomes: *"It opened my eyes to a few things...how my*

steps were affected by what sleep I had...and tracking my patterns on what days I did what."(P10)

Alternatives and future actions: 8 interviewees said that interacting with the system led to reflection on the actions they were currently taking to achieve their goals and made them critically re-evaluate these actions to think about possible alternatives: *"I definitely thought about whether I was doing as much as I could to be able to reach those goals. More about what were the barriers that were making it where I wasn't reaching those goals." (P13).* The prompts also triggered thinking about planning possible strategies to achieve enough physical activity based on what they have learned from the past: *"Partially, it's about reflection, but it's more of planning ahead, like what I should do and what I will do...by reflecting on the past behavior."(P20).* Such reflection was for many participants a prerequisite for trying out new behaviors.

New insights: 4 participants said interacting with the system led to reflection on aspects they had not thought of before, such as considering possible alternative metrics: *"It got me thinking about what other interesting metrics are there?...I had never really thought about what I track or pay attention to that carefully. I just kind of use whatever the given dashboard is." (P14).* In other cases, it triggered critical thinking about how they currently use the metrics that are tracked, and what they can learn from these metrics. The system also introduced new ways to evaluate data by presenting them in a different timeframe (e.g., two weeks): *"It was my first time to see an overview of my weekly activity...I had never done it before. Thinking in a way of a week cycle was interesting...Thinking of two weeks in parallel, is there any seasonality or any cycle." (P20).*

Benefits of reflection
We found that reflection was beneficial in many ways: by increasing motivation towards physical activity, introducing changes to participants' actual behavior, increasing mindfulness, and encouraging the formulation of more realistic strategies for increasing physical activity.

Increased motivation: Many participants found the reflective dialogues to be motivating. 5 interviewees reported that the mere presence of the prompting mechanism provided focus, kept them in check, and consequently led to increased motivation: *"They pushed me, in my opinion, they pushed me to start doing more. And sometimes we need that little push." (P3).* In some cases, the daily presence of the dialogues created a sense of accountability, which provided additional motivation: *"They were a form of encouragement to me, because it's like I knew that there was accountability on my part, that if I had a poor day that I had to explain why, reflect on that on, what would I do the next day." (P22).* 8 interviewees reported that the dialogues helped them realize their barriers, formulate clear action plans and define small, concrete and attainable steps for achieving their goals. Interviewees considered these aspects to be motivating: *"It*

was like 'What little changes could I do?' And that was helpful 'cause like making the time for an hour workout every day seems daunting, but going for a walk on my lunch is doable. Going for a walk after work is doable." (P25)

Leading to new behaviors: For many interviewees, engaging in reflection resulted in the adoption of new behaviors. These behaviors were usually small changes to daily routines, such as parking further away from office or parking meter to walk more, walking to a grocery store instead of taking a car, or using stairs instead of an elevator: *"I actually did little things to make myself more active during the day. The prompts got me like, one day I'm talking about walking more during break, and so since then I've made a point to get out of the office and walk during my lunch. Just doing little things." (P25)*. In some cases, the dialogues served as an additional push on top of a request from a family member, e.g. a request from participant's daughter to go for a walk or an evening walk with wife in case of another participants. In some cases, the prompts also triggered a return to past behaviors that have been abandoned: *"It actually got me to get back into running, which is what I had gotten out of for a little while so that was kind of nice." (P24)*. In a number of cases, the mini-dialogues led to behaviors that facilitate physical activity, such as wearing Fitbit more often, downloading an additional app for tracking running progress or scheduling a class at the gym: *"After I would get the message, if I hadn't already scheduled class at the gym for that day, it would usually be a good reminder." (P14)*

Increased mindfulness and led to more realistic plans: 6 of the interviewees said that the mini-dialogues helped them better assess their progress and become more mindful of their own tendencies and inclinations: *"I realized something about myself that I like to work out…[by doing] another activity. For example, going to the museum." (P14)*. In many cases, this led to an increased understanding of factors that help participants meet their goals, or barriers that prevent participants from reaching their goals: *"I guess just becoming more aware of the barriers to some of the stuff keeping me from my goals." (P26)*. This helped interviewees realize the need for specific and realistic actions to achieve their goals: "I think it helped me be more realistic. A lot of times where you're like 'Oh I can do this in a month or something like that.' But in reality, it's a lot tougher so it's nice to have that reflection" (P24)

Impact of system features

In this section we focus on exploring the impact of 4 key elements of the system: the dialogue structure, daily prompting, the need for typing and sending an answer, and the activity graph based on Fitbit data.

Dialogue structure: Our dialogues were composed of an initial question and a follow-up question, which was overall positively received by interviewees. They felt that the follow-up questions gave them a chance to spend more time reflecting on the initial question, noting that one question

was not enough to engage in meaningful reflection: *"t think if just one prompt might be too short for me to reflect on my activity. I think I need at least like a minute or so experience to really think about how I feel and why I did it and things like that." (P20)*. Alternatively, some participants considered the initial question to be a warm-up to the follow-up question, which encouraged them to answer more truthfully: *"I mean I think it caused me to answer more truthfully, more honestly, or more alertly, so I couldn't just give a one-word answer or anything, I have to kind of think about it a little bit more." (P28)*.

Future work is still needed to help make the interaction more dynamic. While the follow-up questions were generally well-received, a few interviewees did not consider the follow-ups to be sufficiently adaptive, which caused the mini-dialogues to feel computerized: *"I would write the response, and then get a generic response back. It was like, "Are you serious?" It felt a waste of my time, writing a long text." (P8)*.

Daily prompting: All interviewees appreciated receiving one prompt per day. Specifically, 6 felt that having a daily reflective dialogue enabled them to view and reflect on their continual progress: *"Everyday, I am able to see the progress. I am able to reflect on the previous day or the previous week." (P3)*. Four participants also expressed that it helped them focus on a specific day , which lowered the cognitive load of reflection. Furthermore, some participants reported that reflection persisted beyond the dialogue: *"I almost got a whole day thinking about one question, even after I'd already sent the responses out. Which then allowed me to build upon what I was thinking about 'cause of repetition." (P25)*. Finally, daily delivery served as a momentary trigger (e.g., to put Fitbit on or to remind them to walk more). When asked about the frequency of prompts, one participant said: *"You don't want it to go too long in between, because then it starts to feel random. But if you have something that's checking in on you once a day, then it's a way to just check in. It becomes part of the routine." (P32)*.

Typing and sending responses: 7 interviewees stated that writing the response to the reflective questions felt like an additional reinforcement on top of simply thinking about the answer. It caused them to think deeper and forced them to put their thoughts into words. This can act as a commitment device and create a sense of accountability to self: *"It gives you a little sense of accountability…When you take the effort to actually put what you did down, you kind of reflect on your performance. You know if you're lying to yourself or not." (P10)*. For 6 interviewees, the sense that someone (computer or person) was reading their responses led to being more conscious about what they wrote and to a sense of accountability. This happened despite the participants acknowledging that the 'someone' is a computer program: *"It made me feel like I was being accountable to somebody, even if it was just a computer*

program. So I liked that. It made me more motivated." (P23)

Reflection with data: 11 interviewees expressed appreciation for the graphs included with the reflective prompts and considered them crucial for awareness and revealing progress: *"I think them being conjoined was helpful. The graph and then asking me a specific question about that data. Then I really had something to tie my answer to" (P27)*. The visual and personalized nature of the graph was considered particularly engaging and provided additional motivation: *"I think them being conjoined was helpful. The graph and then asking me a specific question about that data. Then I really had something to tie my answer to" (P27)*. Some participants, however, reported the graphs to be redundant given that their Fitbit app already provides a similar visualization.

DISCUSSION
Reflection has been identified as a key element of successful health behavior change [1,2]. However, most existing tools assume that reflection would naturally occur when people visualize data or journal. In our work, we argue that a conversational approach, using what we refer to as "mini-dialogues" design, can be effective for eliciting reflection. Indeed, in our deployment, our system successfully led to reflection at three levels: awareness, understanding and new insights for the future. We show that such reflection can help users become more motivated and can lead to defining action plans better aligned with users' long-term goals and actual abilities.

We believe that the conversational aspect of the system played an important part in the positive outcomes; using dynamic follow-ups, users not only remain engaged with the system, but it also gives users a sense of being listened to. However, making the system appear intelligent runs the risk of it making occasional mistakes that break the "illusion" of intelligence.

In addition to contributing guidelines to reflection system design, this paper also provides several insights on current reflection practices of fitness-trackers users. In particular, our workshops with active Fitbit users show that reflection that these users engage in is often limited, with a current lack of tool support for reflection. Many reported that, when reflecting, they focus predominantly on a day's worth of data or reflect on a single event. They reported a number of barriers that limit their engagement, from perceiving that refection can be boring and repetitive, to lacking engaging triggers to reflect on novel aspects of their data and activity. With our system, we demonstrate that dynamic, daily triggers of reflection may be able to fill this gap.

Much prior work has discuss the importance of reflection in behavior change [28], and has suggested that reflection can lead to greater awareness of underlying needs [27], help people understand their motivations and focus on higher-level goals [11,44], and can help overcome decision biases

and give opportunities to better focus on the actions [34]. Reflective strategies can further help people focus on long-term consequences of their choice and make decisions that are more in line with identities [2], which also makes them more likely to tolerate short term discomfort [17]. Our investigation confirms the potential benefits of reflection for fitness and physical activities.

Similarly, we found that encouraging reflection increases users' awareness of their own behavior pattern, the barriers to their goals and external factors affecting them. In some cases, reflection can lead to new and insightful perspectives on self-tracking data. In that, reflective prompts can serve as a powerful tool for exploration. While most of our participants did not revise their physical-activity goals during the study, many reported that the 2-week period was too short to compel such an revision.

Finally, in this paper, we present our approach for developing reflection prompts. One key challenge with building a conversational system for reflection (or a conversational system in general) is to generate a set of sufficiently diverse and topic-appropriate prompts. In this work, we used a workshop-based approach, akin to participatory design. In general, we found this to be an effective approach; different users had different data and goals, which helped generate a diverse set of prompts for reflection. Using real data also helped ensure the prompts remain relevant and interesting to potential users. It is important to note that we found that it was easier for participants to first brainstorm about awareness, understanding or insights they can/wish to gain from their data, and then rephrase it as a reflective prompt, instead of being asked to generate reflective prompts directly.

CONCLUSION
This paper introduced a conversational system based on mini-dialogues for supporting reflection on physical activity. Our workshop results and deployment findings offer many important insights about reflections for personal informatics and behavior change and how conversational interaction can be designed and used to support the reflection process.

In future work, we plan to make our conversational approach more tailored and able to evolve over time to support users' increasing levels of reflective thinking. We are also considering improvements to our dialogue generation process that may streamline and integrate it with the reflection system.

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