Help Me Help You: Shared Reflection for Personal Data

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ABSTRACT

Dramatic advances in sensor and computing miniaturization for personal data collection are making Personal Informatics (PI) tools a reality. Yet, advances in data collection have not been matched with similar advances in tools to promote, support, and facilitate reflection on this data. This gap leaves people with large swaths of data, but very little understanding of how to make sense of the data or to derive actionable insights. In this work, we explore a process called shared reflection, where individuals are paired with other data collectors, and asked (through prompts) to reflect on one another's data. Based on a six-week study where 15 participants collected different kinds of personal data and engaged in a shared reflection process, we show that participants gained transformative insights from others' reflections on their data. While this was promising, we discuss practical challenges in deploying this idea into real world personal informatics tools. In particular, while shared reflection can be appropriated to effectively bootstrap reflection on one's data, this needs to be balanced against privacy and control concerns.

CCS Concepts

Human-centered computing → Human computer interaction (HCI) → Empirical studies in HCI

Keywords

Shared reflection; personal informatics; personal data analytics; reflection.

1. INTRODUCTION

Personal informatics is the process of collecting personal data, and analyzing this data to facilitate decision-making in one's life [32]. Dramatic increases in computing power (e.g. smartphones) along with increasingly powerful sensing technologies (e.g. [26][5]) have made collecting this data very easy. We are increasingly seeing the use of this tracking technology to improve people's health and well-being (e.g. [3]). This shift is a natural consequence not only of the power of the data tracking and collection technologies, but also the increasingly popular notion of self-directed care (e.g. [6]).

Yet, the presence of data is insufficient to generate actionable insight; rather, Li et al. [32] argue that this can only result from reflecting on one's data to understand what is happening. Like Baumer et al [4], we see the value of reflection in both the possibility of actionable outcomes, and in and of itself as a meaningful self-discovery process (i.e. learning). We take an educational perspective of personal informatics (and therefore reflection)—in this way, people making use of personal informatics tools are learners, and the data gathering efforts are in support of this learning. As with Moon [42], we consider reflection as having a critical role in this learning process. Here, already known information is combined with new information (as a mental reprocessing of knowledge) to produce new knowledge or insight. Thus, reflection represents a form of deeper learning that goes beyond the data itself. In this work, we introduce a strategy called shared reflection that relies on a community of like-minded learners to engage in reciprocal reflection of personal data to help bootstrap one's self-discovery and learning process.

We began with the "learning by teaching" framework, which argues that learners can gain valuable insight into a subject matter by teaching it to others [23]. A simple variation of this idea that has gained popularity in classrooms is peer review of work (e.g. essays, presentations, etc. [52]). Our basic idea with shared reflection was to have learners perform "peer review" of one another's data, providing feedback and analysis of the data—a process we call shared reflection. We expected that this process would result in several benefits: (1) learners receiving direct feedback (and new ideas) about his/her data and collection strategy; (2) a learner gaining experience thinking about data by studying another person's data collection and strategies, and finally (3) the learner being able to take these experiences and reapply the ideas back to his/her own data.

To explore the benefits, challenges, and nuances of shared reflection, we designed and conducted a 6-week study with 15 participants. These participants used the shared reflection strategy as their primary method of reflecting on their data. Based on our analysis of the data, we found that learners benefited substantially from the feedback they would receive, as this provided new perspectives on their data, helping them to derive new insight. Furthermore, being able to see the data collection practices of others was useful. On the other hand, we did not see evidence that learners gained meaningfully from the practice of reflecting on others' data itself. Our study also raised questions about how to properly motivate learners, whether learners need to be collecting the same kinds of data, and how to make the process, which is highly dependent on others, less brittle.

We make two contributions in this paper: first, we articulate shared reflection as a new way to support reflection for personal data; second, we present the results of a formative evaluation of the strategy through a study of 15 participants. We begin by outlining literature that led us to the shared reflection strategy. We then describe several considerations in employing the strategy, and outline the variation we selected for our study. We follow this with the study we conducted, and the findings from this study.

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Finally, we distill lessons from this study, and outline directions for future work.

2. RELATED WORK

As argued by Baumer [2], reflection is increasingly becoming a popular notion within the Human-Computer Interaction domain. This reflects a level of maturity in the field, but also a recognition of the power of reflection as a cognitive process for deeper learning and understanding. Reflection in this sense is a well-known process within the learning community [2][42][48][52][53]. Several researchers have explored this concept in the workplace to support learning (e.g. [44][28][16])—much of this reflects the *in situ* nature of learning in these context, and the idea is to support reflection-on-action [48] through the experiences of others (e.g. [13]). Prilla & Renner [43] for instance, explore the use of TalkReflection as a method to allow employees of public organizations to reflect on and improve in their job functions. This application allowed employees to post "reflections" (short essays) on experiences in the workplace, which then acted as prompts for others to respond. They found that this collaborative reflection supported learning by allowing more experienced members of teams pass on their knowledge and experiences in response to those with less experience.

The utility of reflection as a process motivates our work here. Our specific interest is in how we can use it as a process to support personal informatics—a wholly different domain compared to prior work exploring collaborative reflection. As we will see, the varying approaches to data collection, as well as the type of data that is collected make it unclear whether experience can be passed on in as straightforward a fashion as in a workplace. To set the stage for our work, we describe two areas of work that have inspired and motivated us. First, we outline work in the personal informatics space that explores how we can support reflection of personal data. Second, we describe social learning, and how researchers have leveraged these ideas for technology designs. We then synthesize these lessons as a set of considerations for our work.

2.1 Reflection in Personal Informatics Tools

Personal Informatics (PI) tools are designed and used to give its users data upon which actionable insight can be developed and applied [32]. Li et al. [32] outline a five-stage PI process whereby a person: (1) finds motivation to examine some aspect of his/her life; (2) collects information about that part of his/her life; (3) integrates that data into a meaningful form; (4) reflects on the data resulting in an increase in self-knowledge, and finally (5) takes action by (perhaps) changing his/her behaviour as a consequence of that self-knowledge. While there exists a considerable body of PI work, very little has focused specifically on how to support self-reflection beyond implicit "by glancing" reflection [2] cf. [20].

Prescriptive Reflection. A large body of early work could be described as persuasive technology, where a designer uses the design to persuade the user to behave in a certain way [21]. For instance, Fish'n'Steps [34], UbiFit [14], UbiGreen [27], present interfaces that visualize data where desirable behaviours (e.g. physical activity, "green" modes of transportation) are rewarded with pleasant visualizations and negative behaviours (e.g. lack of exercise) result in unpleasant visualizations: for example, in Fish'n'Steps, the fish look sad, and the UbiFit garden becomes bare without flowers. Similarly, many tools rely on competitive (or at least comparative) social tactics, whereby users could compare their behaviours with others (e.g. [9][17]) or an arbitrary threshold, such as a step count. In these situations, reflection is reduced to a simple question: did I do enough? Finally, we have also seen efforts to present this information in ways that are familiar to the user in the form of natural language (e.g. [6]). In all of these cases, the approach tends to be prescriptive—rather than allowing the user to come to ideas or decisions on his/her own, the tool dictates the "correct choice" for the user to follow. Such an approach may not be appropriate in situations where "correct behavior" is unclear; furthermore, it may be undesirable as it obviates autonomy and self-discovery, which characterise deep learning/reflection [8].

Informational Visualizations for Reflection. Other tools attempt to facilitate discovery through rich visual representation without necessarily imposing a particular interpretation of the data. These efforts have come in the form of visualizations that illustrate highs, lows, and hopefully trends (e.g. [12]). These explorations have touched on many different domains (beyond our scope here), but include things like sleep [11], music listening histories [5], residential water usage [17], to mobility and social interactions [15], and even activity [20]. Importantly, these kinds of visualizations rely on the viewer to interpret the visualization, to make sense of it, and understand it within his or her context [24]. In effect, they support self-discovery.

This "self-discovery" support perspective resonates with us in that it is a *personal interpretation* of one's *own data*, and one arrives at it from one's *own perspective*. Depending on personal circumstances, people may need to interpret data in very different ways. For instance, MacLeod et al. [36] report on a participant who will consume alcohol even though it may cause a him a seizure, because it was acceptable to him in certain social situations.

Deliberate Engagement for Reflection. Very recent efforts by Baumer and colleagues' work can be seen as a reaction to these, where rather than relying on users to reflect of their own accord, the design deliberately engages people with their data and the reflective process (e.g. [3][4][30]). For instance, Baumer [3] noticed that people began reinterpreting photos of what was healthful, rather than adhering to what might be prescriptive norms. Similarly, Khovanskaya et al. [30] explore reflection on the infrastructure of data collection by provoking it deliberately through a design that reflects either a brokenness, or a creepiness, etc. Thudt et al. [51] explore the design of playful, interactive visualizations as a way to engage the reflective process through search. Finally, Baumer [2] focuses on the concept of reflection by articulating several different perspectives from which we can consider reflection (philosophical, cognitive, critical, learning), and articulating new axes upon which we can engage reflective process (breakdowns, inquiry, critique).

Our work here builds on the ideas outlined by Baumer [2]—specifically, we are interested in "bootstrapping" reflection as a learning process. Like Isaacs et al [29], we explicitly engage learners in the process of reflection: both on their own data, and on others' data. In so doing, we are interested in engaging the cognitive process of reflection by having people considering the challenges of others (i.e. thereby making it a social task).

2.2 Social Learning for Personal Informatics

The Quantified Self (QS) movement is an open membership organization that promotes self-learning through data collection. In their exploration of how Quantified Selfers learn from their data, Choe et al. [12] discuss the important role of Quantified Self Meetups (gatherings or meetings). Here, members share and

articulate what they have learned, asking and answering questions from other Quantified Selfers about their process. Presenting members consequently need to make their learnings coherent through a storytelling process; furthermore, attendees benefit from being able to engage in active inquiry (i.e. question asking). Learning theorists from the constructivist tradition place strong value on such social processes in learning [53]. This perspective suggests that learning comes from a type of active inquiry—asking questions. The dialogue from storytelling and explanation also reveals underlying assumptions, etc. that can prompt conversation (and therefore additional learning). This type of "deeper learning" matches with adult learners' motivations—specifically, that they are interested in developing new knowledge based on their existing knowledge, and being critical of what is being taught [8].

Asking Questions. Many researchers have explored how people use online systems to support asking questions in a variety of contexts (e.g. technical questions [38], health [13], etc.). One challenge with this approach, however, is that it depends on people being able to frame their query in terms of an explicit question. An interesting approach to this problem has been to consider non-explicit queries, where the question is implicit based on users' (learners') interactions with a system. Bateman et al. [1] provide users with search terms/results that colleagues have used, and do so in-context while users are typing in their own search queries. Chilana et al. [10] explore a similar approach, providing users with tooltip web search queries for features that a user is exploring. Here, the queries are mined from the web rather than gathered from a known expert. These approaches are unique because rather than presupposing a correct answer, the central premise is to gather information on behalf the user, and allow the user to choose to make use of it.

Getting Feedback. Prompting this active inquiry and learning without dictating the outcome of the learning is challenging, particularly when the learners are novices. Luther et al.'s efforts are instructive: here, novices on a crowdsourcing platform are asked to provide critiques of visual/interaction designs [35]. The authors noted that by providing these novices with some scaffolding (by way of a rubric), they were able to generate critiques that were meaningfully usable by designers afterward. Similarly, Tinapple et al. [52] study how peer-based critique can be supported in a classroom using a tool call Critviz. In both cases, there was some evidence that the people providing the critiques were themselves learning how to produce more effectively.

In the personal informatics domain, we are interested in this type of feedback, because rather than knowing a priori what kind of feedback is appropriate and necessary, how to interpret the data is unclear. Here, the meaning is ambiguous, depends on the person reading the data, and it is a rich diversity of feedback that is valued. Sadler [47] provides a framework suggesting good feedback allows learners to understand what is intended (conceptual), to compare themselves to that standard (specific), and provides direction to take steps towards that standard (actionable). In the personal informatics domain, such a framework may not be applicable. Thus, the core idea is then to gather the feedback, present it to the learner, and allow him/her to interpret it.

3. SHARED REFLECTION

To address the challenge of supporting reflection in personal informatics, we formulated a set of basic ideas around the idea of learners providing reciprocal feedback as a way to deliberately engage with reflection. These were grounded in prior literature on the use of critique and feedback [35][52]. Here, we outline some considerations on this idea, describe the process that we chose as a way of instantiating those considerations, and describe the benefits that we expected from this process. Later, in our study, we evaluate and expand on these considerations to form a more nuanced understanding of shared reflection.

3.1 Considerations

Learning through active (prompted) engagement with data. Rather than relying on people to simply think about their data on their own, we feel that shared reflection should rely on active participation in a reflective process. Here, we specifically are interested in ways of prompting people to take time to actively think about the data rather than relying on them to find time to do it at their leisure. Like Baumer [2], we feel that engagement needs to go beyond looking at tables of numbers.

Verbalizing reflection as prose / narrative makes it concrete. We have seen that many people from the QS movement benefit from QS meetups, where they discuss their experiences of collecting and making sense of their data [12]. This type of storytelling (and indeed, preparing for the storytelling) likely supports reflection, transforming it from disconnected abstract thoughts to something much more concrete. This verbalizing (whether oral or written) makes it a more definite narrative, and we believe this will encourage people to gain more meaningful insight. For instance, if one were making an assertion about another person's data as feedback, one would likely work to ensure that the assertion was appropriately supported by the data (or, at the least, to explain one's thinking process).

Other people do things differently than us. Leverage this as a source of surprise and inspiration. This consideration is at the heart of our thinking about shared reflection. Seeing other people's data and reflecting on it is easier than trying to derive new insight (or questions) of one's own data, because others collect different kinds of data, perform the collection differently, or have different goals than us. We thus have perspectives that are different from others, and might be worth sharing. By the same token, seeing what others have to say about one's own data can cause reflection because it may prompt a breakdown or surprise (i.e. "Oh, I never thought of it that way."). This kind of breakdown is important in prompting transformative changes in how people think [2].

3.2 Process, Alternatives and Drawbacks

Initially, we imagined a four-part process for shared reflection. For example, we assume two data collectors, Alice and Bob, have collected data about themselves.

1. **Trade data.** Alice sends her data to Bob; Bob sends his data to Alice.
2. **Reflect on someone else's data.** Alice reflects on Bob's data, and writes him feedback based on her perspective; Bob does the same for Alice's data.
3. **Trade feedback.** Alice sends her feedback to Bob; Bob does the same.
4. **Reflect on feedback.** Alice reflects on her data and the feedback she received from Bob by writing a paragraph. Bob does the same.
5. **Repeat.** The process repeats with additional data collection.

Each step of the process demands active engagement from learners. The first step requires packaging up one's data in a way

that is interpretable to others, potentially along with information about how to understand the data that is being collected and why. The second step reveals how others are doing collection, and asks collectors to reflect on that practice and what is in front of them in an active way, preparing a verbal narrative as feedback to the other learner. The third step provides the learner with someone else's feedback. In the fourth step, the learner is now asked to explicitly reflect on that feedback (along with the original data) by preparing a written statement. Throughout this, the learner can revisit his data collection strategy or goals as a consequence of what has been learned.

In our study, we used a variation of this process. Since there were many people in the network, we simply gave each participant someone else's data to study and provide feedback on (i.e. rather than necessarily swapping within a pair). We settled on this process after considering several variations on the above-listed basic process. Our final approach to this process was mainly due to pragmatic considerations of conducting the study, but raises several open questions:

Dialogue. *Should Bob see Alice's response to Bob's feedback once Alice has written it? And, should Bob be given another chance to respond?* To make it clear what we expected of participants (and partly to protect their identities from one another), we did not provide participants with a mechanism to communicate with one another directly. Instead, all communication went through the first author via email.

Homogenous data collection. *Do Alice and Bob need to be collecting similar kinds of data?* We considered allowing feedback only from participants collecting similar kinds of data (as they would be more familiar with the domain), but also the opposite of that scenario, where participants would only give feedback to those collecting different kinds of data (as they would be more apt to provide a unique perspective). In our study, we opened it up to any kind of data collection—participants did not need to be collecting the same kind of data. This was a pragmatic choice: we were interested more in the notion that participants would benefit from getting a variety of perspectives on their data collection, rather than in feedback strictly from people familiar with the domain.

Anonymous feedback. *Should Alice and Bob remain anonymous? Would it be more likely in a real-world scenario that family members would be providing feedback?* To protect participants' anonymity, we opted for anonymous feedback in our study.

Making it "public." *Should all data, feedback, and reflections be open to all participants?* Other systems such as Critviz [52] provide all data and feedback in an open forum. This has the benefit of allowing people to "dive deep" into all the content and ideas that have been generated by others—regardless of whether the feedback is about one's own work. It thus gives learners access to a wide range of ideas right away, and potentially right at the point where they are interested in thinking more about new possibilities. We chose not to do this in this study. While there is great learning potential in this approach, we were interested in whether the feedback *on its own* would induce meaningful reflection, and keeping a simple model of feedback would allow us to trace the source of inspiration.

Stratification based on experience. *Should novices be getting feedback from other novices?* We considered pairing novice data collectors with more experienced ones, but realized that the metric for expertise was not only highly subjective but that expertise might actually be a domain-specific. Thus, for the purpose of our study, we did not use this strategy.

Drawbacks. One drawback of the process as outlined above is that it is time and labour intensive. It takes time on the part of learners and does not come without effort. Another drawback is that even though we have taken steps to maintain the anonymity of participants by not sharing their names or contact information with one another, they are still sharing personal data about themselves. While it turned out not to be the case in our study, some types of personal data can be used to identify someone (e.g. GPS/location data). If a learner wants his data to remain private, this may be problematic with shared reflection due to the explicit demand to share the data with someone else.

4. Study

We designed and conducted a study to understand the strengths and weaknesses of our shared reflection process and to learn how we could improve it. As outlined earlier, the shared reflection process asks people to analyze and reflect on others' data, to receive others' feedback on one's own data, and to explicitly reflect on one's data. Our interest here was to understand how these additional tasks of analyzing others' data (and getting others' feedback) would influence our participants' understanding of their own data. Thus, we focused on two research questions in this study:

1. How does receiving feedback from another person assist/change one's own reflection process?
2. How does reflecting on another person's data support change in one's own reflection process?

4.1 Participants

A total of 15 participants (9 females) were recruited for the main study with ages ranging from 20-74 (median 38). Participants were located across Canada and the United States. Four additional participants were recruited for a pilot study, two of whom were ultimately rolled into the main study. Participants were recruited via public advertising spaces, email lists, Meetup groups, presentations, and in-person. Advertisements asked for people who were interested in personal data collection (whether they currently collected data or not) and in learning more about themselves. Participants were remunerated with up to $20 for participating in the study and entered into a draw for $100 on completion of the study.

4.2 Design

We designed a six-week field study with three phases:

Phase 1: Pre-Study Questionnaire. The online pre-study questionnaire collected demographics, experience and current practices in data collection (if any), and responses to a set of structured questions to help participants identify personal goals for the study (i.e. what data would they collect and to what end). For instance: Whether or not you currently collect data, what data are you interested in collecting? Why are you interested in collecting this data? What are you expecting to learn from this study?

Phase 2: Data Collection and Reflection (6-weeks). For six weeks, participants collected data. Participants were asked to collect data in an activity log. Participants were free to choose the type of data that was to be collected, and how it was to be recorded (a sample log was provided if needed). At the end of each week, participants submitted their data collection logs.

Starting at week two, participants were given a week's worth of data from another participant in the study and asked to provide some feedback about it. This feedback was submitted to the researchers and then returned to the original owner anonymously. The original owner would then be asked to study and think about this feedback before writing a response. This response was then submitted to the researchers. Each week, participants were given the data of a different participant if possible. These activities were repeated each week until the end of week six.

Phase 3: Post-Study Questionnaire. After the last week of data collection, participants completed a post-study questionnaire which asked them to reflect on what they had done and learned over the last six weeks. For instance: Has your understanding of your data collection changed? What have you learned from this study? Were you able to fulfill your objectives?

Participants were free to choose their goals and the type(s) of data they wanted to collect for the duration of the study. In addition, they were allowed to choose the way in which they collected the data (i.e. using activity trackers, using mobile applications, by hand, etc.).

4.2.1 Pilot Study

Our resulting field-study approach was informed by a pilot study where we compared the shared reflection approach to a control condition (e.g. no externally supported reflection). The controls in this pilot test did not report any meaningful change in their understanding of themselves or their data. In contrast, the two pilot participants who were in the shared reflection condition had already started to demonstrate that they were learning from working with one another through their shared reflection process. These participants expressed very high levels of motivation in comparison to the other participants. As a consequence, we began the main study, adding these two participants into the main study (i.e. without changing their protocol).

4.3 Data and Analysis

We collected three sources of data: pre-study questionnaires, submitted content from participants during the study, and the post-study questionnaires. The submitted content included the following for each participant: their submitted data, the feedback they received from other participants on their data, and their reflections on that feedback. The pre-study and post-study questionnaires allowed us to see the difference between what they thought they understood from their data to what they had at the outset, and the submitted content allowed us to track this change through their process.

We conducted a thematic analysis of the data, iteratively identifying and exploring patterns that we observed within the data. We focused on the types of ideas being expressed by participants in their feedback and the responses that participants generated to that feedback. Each idea was thematically coded using an open coding process, allowing us to see when and how ideas were introduced to participants and how they appropriated these ideas into their own reflective processes.

Coding process. Each piece of submitted feedback or response were divided into phrases. Most phrases were complete sentences, though some sentences contained multiple phrases. Each phrase was evaluated and assigned a code. This process was repeated for all phrases in all weeks for each participant, where we added codes to the master list as needed. Once the initial coding was done, a second person reviewed the codes for consistency and validation.

For example, when coding a phrase from a participant ("The amount of data collected is sustainable, but if other sorts of data could also be collected, it may help narrow down causal variables."), this phrase would be coded with two different codes. The first part of the phrase ("The amount of data collected is sustainable") would be coded as an *Observation*. The second part of the phrase ("if other sorts of data could also be collected, it may help narrow down causal variables.") would be coded as a *Suggestion*.

4.4 Data Collected

Table 1 summarizes the types of data that participants tracked. Participants were free to record the data in whatever way they wanted (some used paper diaries, others used Excel, and so forth). Although many participants chose to track one type of data, some participants experimented with multiple types, either dropping some as they discovered they were not interesting after a few weeks, or completely changing what they were collecting. Participants were aware that their data would be shared with other participants, but none expressed that this sharing affected their choice of what data they would track.

Over the course of the study, one third of participants changed the data they were collecting in some way. Some people found that the data they initially chose to collect was not getting them the information they were hoping for, so they completely changed their goals and data type. Of the participants who changed the data they were collecting, most of them (60%) made their modifications in Week 3 (i.e. after one round of feedback). It is interesting to note that all of these participants were also collecting multiple types of data. One participant showed a clear refinement of their initial goal as they learned the benefits and drawbacks of what they initially chose to collect.

When the data was passed between participants (i.e. from the collector to the person providing feedback), it was done so in raw form. In many cases, these would be simple tables of data—usually with columns like date, description, amount—however, this varied widely depending on the kind of data that was being collected. There was no common visualization tool provided.

Participant	Data Collected
P1	Physical activity (6 weeks)
P2	Food (5 weeks), time (6 weeks)
P3	Teaching effectiveness (6 weeks)
P4	Physical activity (2 weeks), mileage (4 weeks)
P5	Physical activity (6 weeks)
P6	Physical activity (6 weeks)
P7	Screen time (6 weeks)
P8	Physical activity (6 weeks)
P9	Music practice time (6 weeks)
P10	Wearing aligners (3 weeks), physical activity (3 weeks), physical ailments (6 weeks)
P11	Physical activity (2 weeks), study time (6 weeks)
P12	Weather (6 weeks)
P13	Food (6 weeks), physical activity (4 weeks)
P14	Physical activity (6 weeks)
P15	Mileage (6 weeks)

Table 1. Summary of the data collected by main study participants.

4.5 Exemplars

We begin by providing commentary on three participants, where their experiences accord with three clusters of participants. These general clusters generally reflected participants' experience prior experience with data collection (none, some, a lot): within each of the three clusters, participants' reactions to shared reflection were

relatively similar. We describe these as personal stories, as the concreteness of each participant's experiences explain the role of shared reflection in their learning. We chose three participants: one with no experience collecting data, one with a limited amount of experience collecting, and finally one with considerable data collection experience to demonstrate how the shared reflection process affected their practices. As illustrated by Table 1, these participants were not necessarily representative of a cluster in terms of the data that was collected; rather, we focus here primarily on their experience of shared reflection. These exemplars were chosen because their responses to the feedback were descriptively rich.

4.5.1 Sarah: No Data Collection Experience

Sarah had not previously collected data. Initially, Sarah collected three types of data: information about her teeth aligner usage to ensure she was using them the recommended 20-22 hours per day, ear aches to determine what factors might instigate them, and pushups to strengthen her arms. As the study progressed, she dropped all but the earache data. She refined her earache tracking to determining which foods worsened the symptoms. Sarah's experience represents three participants in the study.

As the study progressed, she figured out what types of data were most interesting and relevant to her while removing unnecessary data. Many changes to Sarah's process was prompted by others: for instance, from week 4, Sarah modified her pain scale from 1-10 to 1-5—this allowed her to not worry so much about the granularity of the pain, but record quickly a rough sense of the magnitude. Sarah also regularly shared resources (links to articles, etc.) to others, and received such links from another participant (i.e. via the feedback that she wrote to others, or via the feedback that she received). Her responses indicate that she had read through these links and had found them interesting and useful.

In the post-study survey, Sarah expressed that she felt as though she learned a lot from the study. In particular, she identified that learning the right kind of data to collect was very important—something that is reflected in the evolution of her data collection over the six weeks. Although Sarah did not fulfill her objectives from the pre-study survey, she also acknowledged her goals had changed, and that she did meet her goals in some other areas. This is a common occurrence for people new to data collection [32], and is often prompted by reflection. Of note, Sarah pointed out that there were the benefits of seeing what other people were doing in their personal data collection practices, as they helped her to make changes to her own process.

4.5.2 Esther: Limited Data Collection Experience

Esther collects and reviews data, but does not know how to use the data. For the duration of the study, Esther collected music practice data with the goal of improving musical performance. Esther, in her experience and focus, represents nine participants in the study.

Esther's logs included time/date of practice, duration, a description of what was practiced, and then a set of annotated notes. These notes were useful to the reviewers, as they found a way of cutting through the raw data to understand what Esther was trying to do, or reasons for shorter practice sessions. In addition, Esther provided other kinds of data on various weeks: sound clips of musical passages that she had difficulty with, or had finally perfected.

Esther took the feedback very seriously, reflecting on the comments and changing her process as suggested. For instance, in Week 5, a commenter suggested:

> I think that the notes section of these data files would benefit from a bit more direction and focus. If the goal is to play through songs without any mistakes, perhaps by recording trouble sections, areas where you'd like to improve on, etc, it could help pinpoint exactly where you most need to improve. – Week 5 commenter

> "More direction and focus" is exactly what my practice needs, plus clear insights into "trouble" sections of various songs -- certain areas where I repeatedly find myself stumbling and making the same mistakes over and over again… I will try to record more, since my digital piano has that capability, so I can be more aware of when and where my mistakes are most likely to occur, in order to work on those sections. I will also try to be more "mindful" of my physical and mental responses, so I can correlate them with the likelihood of fumbling, as well as whether my pain levels affect my playing ability, or whether I'm able to "play through" them. – Esther's response

This vignette illustrates how shared reflection worked for Esther. First, the commenter identifies and articulates the central issue for Esther in a way that she finds exciting. Second, the commenter provides a bit of direction as to how to execute on addressing the issue. Then, Esther takes that idea and pushes it in a direction that resonates and makes sense for her. This means that Esther not only changes the process through which she collects and makes sense of data, but that the way in which she is thinking about her goals has evolved.

In one case for Esther, the commenter misinterpreted her comments about pain in her hands (from practices) as being something that needed to be overcome (not Esther's intention). Based on this though, Esther realizes that an underlying issue for her has been carpal tunnel, and ends up finding a potential solution to the problem:

> The part about ***things usually get better*** (above) didn't exactly materialize that way, in my case, as far as my practicing the [ukulele] went… I did a little online research and found out that CTS is common among musicians, and that they benefit from doing stretching exercises before practicing, like athletes do before they work out. I did some of the exercises suggested in a couple of online articles before I practiced the piano today (1/2 hour) to see if that helped. – Esther's response to week 4 feedback (emphasis was hers, quoting the feedback)

In this case, the stretching did not help, but in some ways, it is immaterial. The point is that the feedback comment, even if it was a bit offside, was clearly a different perspective on Esther's situation. It sent her down a path of self-discovery to actions that she had never considered.

Esther took the feedback and reflection very seriously. Her responses were thoughtful and nuanced. Though she responded more deeply to the comments she received than most participants, she represents our participants in this cluster in the sense that they would consider the suggestions and sometimes end up taking them on in their practice.

In the post-study survey, Esther mentioned that seeing other participant's data logs were helpful to her in terms of seeing what other people collected. She felt that she learned a lot about herself throughout the study including what factors affected her practices. Another point Esther made was that she was more motivated to continue practicing regularly due to keeping regular logs. She was also interested in finding out what other people in the study had learned, which hints at an interest in some sort of interaction with others.

This exemplar illustrates one way in which someone with minimal knowledge of data collection can explore personal goals and refine activities to align with personal values and objectives. In Esther's case, there is clear evidence of exploring different types

Code (count)	Description	Example
Observation (74)	Re-iterating the data	I'm not sure I got everything, but what I got was related to aligners being in or out, pushups, what foods were affecting tinnitus.
Extrapolation (45)	Interpreting the data	I assume it's a teenager or young adult.
Suggestion (99)	Ideas to make changes to data collection or interpret data	I may suggest changing the ringing scale to 5, with 5 being worst and 0 being non-existent.
Sharing (57)	Providing resources such as books, articles, etc or referencing personal experiences	I did similar food tracking...and it helped a lot
Support (113)	Providing words of encouragement	This is a great data sample.
Clarification (40)	Asking questions to better understand the data or person collecting the data	How long has this person been collecting data?
Shout Out (1)	Request for information from others	Anyone know any exercises to relieve the symptoms ... in my thumb, especially?

Table 2: Codes for participants' feedback on others' data.

of data collection, refining goals, and reacting to other people's feedback by both accepting and rejecting suggestions.

4.5.3 Larry: Significant Data Collection Experience

Larry collects data, and saw this as an opportunity to push his understanding of his data. Larry's goal was to track physical metrics, activities, and diet to lose fat and gain muscle. Of note, Larry makes use of graphs to analyze his data. This case represents three participants in the study.

Larry did not make use of the provided template in his data collection. Starting in Week 1, it was apparent he was familiar with the area in which he was collecting data. His goal was fairly well defined and the justification of his methods and processes were extremely precise. An interesting part of Larry's data is that he used cumulative data collection and included cumulative graphs in his weekly submissions.

In responding to comments, Larry mentioned that some of the comments he received from others did not provide enough constructive criticism on his methods. Thus, he was somewhat disappointed in what shared reflection was able to provide him. Many of his concerns were centred around extrapolating meaningful information from his data, which he wanted more thoughts on. Starting in Week 4, Larry's comments become much shorter and he spent minimal time extrapolating his data. At this point, he mentioned that he believed he had extracted most of the interesting information from the data in previous weeks and didn't feel the need to re-iterate what had already been learned. Thus, at this point in the study, the shared reflection method was providing limited benefit despite the extra efforts he needed to leave comments for others and read theirs on his data.

Larry illustrates how an experienced data collector may not stay motivated/engaged with a shared reflection process for a long period of time. It seemed as though Larry's engagement declined once he no longer saw personal gains in the process.

4.6 Findings

Our findings suggest that participants gained valuable insight from the shared reflection process. Mainly, these insights came directly from feedback received from others, where participants would indicate that they made changes based on this feedback. In a limited number of cases (as with Sarah and Esther, above), participants indicated that the act of reviewing others' data was useful in helping them to understand new possibilities (e.g. data collection strategies). Furthermore, as in Larry case (above), some participants seemed to reach a "ceiling effect," where others' feedback no longer helped them in their reflection.

Overall Learning. When asked what they learned in the study, participants answered the question in a variety of ways. Some focused on what they learned from their data (5/15) while others focused on what strategies and techniques they learned (10/15). A few of the participants (3/15) highlighted interactions with other participants in some way in their responses. These people found it interesting to see what other people were doing and also felt more motivated to keep up with their data collection when they knew they would be held accountable.

To understand the nature, role, and impact of the feedback that participants receive, we frame the reminder of our findings in three sections: first, we describe the nature of the feedback that participants sent to others; second, we discuss participants' reactions to this feedback, and finally, we articulate several salient challenges that became apparent in our study.

4.6.1 Feedback on Others' Data

We coded both the feedback participants generated for others and that which they supplied in their self-reflections. Table 2 illustrates the final codes that our process produced, along with the number of phrases that were coded with those categories.

Support. The most popular code was support, where the feedback was mainly intended as social support (akin to [49]). For instance:

> "It takes a lot of motivation to make it out every day, especially in the winter, so good to see training sessions for 3 consecutive days." - from P1's analysis of P4's data (code: support)

> "I can tell you are trying really hard" - from P2's analysis of P6's data (code: support)

Such comments were rarely actionably useful for the participant receiving the feedback, though from prior work, we know that such words of encouragement have two effects on participants: (1) it can make them feel accountable to others, and (2) it can help encourage them to continue in their practice.

Observations and suggestions. Participants seemed eager to help others out as much as possible and often tried to make sense of the data by writing out their observations as a way of framing advice or suggestions.

> "It looks as though there are 2 weeks of data from a runner/jogger keeping track of distances run, both with a partner and alone, in order to increase endurance & cardiovascular performance, with the goal of working up to 50 km (31.0686 miles), "even ONCE A DAY!"." - from P9's analysis of P4's data (code: observation)

Based on their observations, they frequently offered suggestions to improve data collection practices. The nature of these suggestions were far ranging. Some would suggest simple data presentation practices for legibility/interpretability:

Code (count)	Description	Example
Response (123)	Addressing comments provided by another participant	Thanks for the comments, which, obviously, someone put a great deal of thought into before expressed.
Observation (51)	Re-iterating the data	The main data I'm concerned with is distance and speed
Extrapolation (82)	Interpreting the data	While the scale doesn't show much improvement, I believe my energy level and overall health and well-being has improved
Re-evaluation (30)	Revising data collection or evaluation methods	The first...offered some time management advice, where the second...offered a method of improving my training tracing through the addition of including comments. I am hoping to put both into practice.
Speculation (30)	Guessing what could happen in the future	I had hoped that adding exercise, without changing my diet, would result in more weight loss
Sharing (89)	Providing resources such as books, articles, etc or referencing personal experience	The following study, which I just completed, inspired an engrossing piano practice session afterward

Table 3: Codes for participants' responses to others' feedback

> "... I would suggest putting sub-totals for each category." - from P6's analysis of P2's data (code: suggestion)

Others would go a bit deeper, offering suggestions for alternate ways to collect, or alternate measures to collect in order to help the original participant achieve his/her goals:

> "... one thing I would suggest is trying to use other sensors, such as heart rate monitors etc. to find an approximate calorie deficit created by the exercise" - from P11's analysis of P14's data (code: suggestion)

Some suggestions offered alternate ways for participants to think about their data:

> "It would be interesting to learn more about your experiences and see additional data collected alongside it. What was your mood like? Was the exercise too much? Too little? Did you feel pushed?" - from P2's analysis of P1's data (code: clarification and suggestion)

> "I would be interested to see the total number of contributions vs the number of different students that spoke." - from P1's analysis of P3's data (code: suggestion)

These kinds of suggestions are far richer, and potentially provocative. Here, the participants offer opportunities for the original participant to engage in reflection on breakdowns (i.e. changes in how they considered the data), and potentially transforming how they now can think about the data [2]. In the next section, we discuss how these suggestions affected participants' practice.

Sharing as suggestions. By chance, some participants were paired with others who had similar goals in the past. In these cases, the feedback took on a reflective tone: participants shared knowledge and resources from their own past to their partner as a way of supporting or providing suggestion. We observed instances where participants would share personal experiences, to suggesting books or articles that they thought would be useful.

> "... I did some research on practicing habits and such when I was starting out and I found this helpful article on making the most of practice time, it is attached, maybe it will help this participant as well." - from P1's analysis of P9's data (code: sharing)

4.6.2 Responding to Others' Feedback

We also coded participants' reflections on the feedback they received (Table 3). When reflecting on their own data, participants tended to spend a lot of time acknowledging and responding to the comments provided by other participants. Overall, this is encouraging, as it means that the feedback acted as a new anchor upon which to think about their data. Here, we see P12 simply responding to questions that P15 had posted about her data:

> "Thank-you for the nice comment on my data. I just use it for year to year comparisons of the date and what the weather was like the previous year..." - from P12's reflection on P15's feedback (codes: response and response)

A lot of participants' follow-up comments seemed in direct response to the feedback they received. Although it was clear the participants would not see these responses to feedback, it seemed natural for participants to write their responses in this way.

New observations. There were some instances of participants making observations about their data based on the feedback they had received. In many cases, such reflections now seemed liked revelations based on what the feedback writer had written (say as a benchmark)—a "breakdown" in Baumer's terms [2]:

> "My weight fluctuates a lot" - from P5's reflection on P10's feedback (code: observation)

> "The gas part of the study is fluctuating" - from P15's reflection on P1's feedback (code: observation)

> "I see I stayed up with a screen often" - from P7's reflection on P14's feedback (code: observation)

Rationalizing choices. Other comments made by participants included re-evaluating their methods based on other participant's comments or their own extrapolations and speculations on what may happen in the future if they were to perform certain actions. Again, these are examples of transformative reflection (Baumer [2]), as they are fundamentally changing how the participant thinks about the problem at hand—beyond simply how one needs to think about analysis, and even how the data is to be collected.

Here, P2 has suggested that P8 consider collecting additional information to help P8 to achieve his goal of losing weight, including caloric intake, hunger pangs, and mood. P8's response indicates that he has given it some thought, but has chosen not to follow through:

> "This would be something I would consider making a diary of to incorporate it with my lifestyle after I am in the routine. I think if I was to make recording to much information at this point would perhaps work in reverse for me as I don't want to make this a "make work" activity." - from P8's reflection on P2's feedback (codes: re-evaluation and speculation)

In providing comments on P10's data, P5 made a suggestion for the scale P10 was using:

> "As a note on the ringing scale. The values go from 3 to 7 to 8. I may suggest changing the ringing scale to 5, with 5 being worst and 0 being non-existent. I made this suggestion simply because the variable cannot be measured, and a smaller scale may help reduce ambiguities in the intensity between close values." - from P5's analysis of P10's data (code: suggestion)

Although P10 did not explicitly address this in their reflection, the data log they submitted the following week showed a change in their scale from 1-10 to 1-5.

Transforming reflection. Based on feedback they received, some participants acted on a question and actively re-interpreted their data. Here, we see P7 re-evaluating his data to determine trends. This is a transformative reflection [2], as it shows that P7 is actively reconsidering the way he thinks about his data:

> "Through week three, I learned I wake-up later if I spend less time with backlit screens at night: r=-0.78 (r^2=0.6)." - from P7's reflection on P9's feedback (code: extrapolation)

In the following reflection, P9 references both P4's comments and P1's resource in enhancing their practice sessions:

> "I will keep those above comments about my diaries, along with those of the person who sent the article on how to practice, by my piano for handy reference." - from P9's reflection on P4's feedback (code: response)

4.6.3 Challenges

We noted several challenges participants encountered in our study. These challenges included issues with our concrete instantiation of shared reflection, and also perhaps limits with the approach itself.

Clarification required/desired. Many participants found it frustrating that they were writing in a one-way fashion. When writing feedback, they could not be certain they were interpreting the data or the original participant's goals properly. Some found it exciting to have a "kindred spirit" who was performing the same kind of data collection; however, it was frustrating that queries could not be responded to.

Some of the participants attempted to extrapolate the data and make sense of what was going on in others' data. In these cases, they often wished to clarify their understanding with more background information on why the data was being collected and the history of the collector. It is unclear exactly what the purpose of these kinds of comments were, as participants were not actually engaged in a (repeated) dialogue with one another; however, it seems clear that in some cases, an ongoing dialogue would have been preferred over the "one and done" approach our protocol mandated. Here, P6 seems to be trying to make sure that s/he is understanding what is being collected (i.e. articulating his/her assumptions of the data):

> "Screen time, I am guessing might include watching tv/movies, computer work/email/internet, and gaming." - from P6's analysis of P7's data (code: extrapolation)

In another instance, P9 seems to ask a question of P4 (for P9's sake) within the context of responding to and thinking about P4's data. But, P9's query here, even though it was a real cry for attention, would not get a response in our instantiation of shared reflection:

> "Anyone know any exercises to relieve the symptoms (numbness, tingling, pain) in my thumb, especially?" - from P9's analysis of P4's data (code: shout out)

Similarly, participants were sometimes prompted by an interesting idea or insight. Here, a participant seems very excited about the possibility of interacting with the "owner" of the data, but is stymied by our instantiation, which does not allow for direct contact:

> "I'd also be curious to know what the person's reaction was to seeing the comment that I sent them about their own data. I want some sort of anonymous discussion with the person." - from P2's reflection on P8's feedback (code: response)

Ceiling effect. As in Larry's case, we observed a sort of "ceiling effect," where he does not seem to be learning anything new from the ongoing feedback cycle. It is hard to know exactly what to make of this—whether there really is no more to be discovered in the data, or that Larry's fellow participants were simply not generating new insight for him. Nevertheless, it seemed clear that for a small minority of participants (3), they reached a stage of saturation before the entire six weeks was up. While these participants stayed on until the end, the richness of their reflections tailed off over time. This might be a fundamental limitation of the shared reflection approach.

5. DISCUSSION

Our study suggests that shared reflection as an idea shows potential in terms of helping people to engage with their data, and the reflection process. Specifically, we saw that people clearly benefited from getting feedback from others, and this helped them to reframe their understanding of either their data or collection strategy/process. Furthermore, by viewing others' data and trying to understand their data collection practices, participants found the process helpful. On the other hand, we did not uncover concrete evidence that participants benefited from *writing feedback* for others. To be clear: we expected participants to learn by writing feedback for others; however, our suspicion is that we simply did not have a good way of assessing whether this kind of learning actually took place. We outline a number of practical challenges that need to be overcome for shared reflection to work in the real world:

Dialogue, anonymity, and "making it public." Our approach of having people write feedback, and respond to it when received from others made the interaction between participants very hollow. In effect, we asked people to care, at least for a while, about one another in their pursuit of their goals. Yet, we did not provide any means for them to follow up on the progress of others. Although this suited the purpose of our study, it seems that facilitating further interaction (while not forcing it) might allow for the supportive aspects of such health sharing sites to surface (e.g. [3][49]). Others have seen that the support can meaningfully impact not only motivation, but a sense of community, belonging, and adherence to activities that support one's goals [19]. The down side of supporting this type of dialogue is that people providing feedback might feel frustrated if their feedback/comments are not taken into account in subsequent data collection cycles. This could discourage further engagement and participation, which would be undesirable.

If supporting dialogue is an approach to be taken, then strict anonymity may prevent real bonds from forming. From an ethical perspective, we chose to protect participants' identity, but this goal would be obviated if participants were voluntarily joining up on a site for the express purpose of helping one another out. This is not to say that real identities need to be used; rather that the source of contributions (be they data, or feedback, or just comments) should be identifiable (i.e. with pseudonyms).

Finally, we saw that participants enjoyed seeing what others had already collected in terms of their process and data. Being able to see this information, if it were public, would provide a source of inspiration for people that are early in their personal informatics journey. Furthermore, it could also be used as a template (e.g. if someone else has similar goals, and has already successfully collected data to that effect).

Homogeneity of data and expertise. As discussed at length earlier, we did not, in this study, address the issue of homogeneity of data collection, or the expertise issue. While we chose not to do

so here for practical reasons, it does seem likely that people who are familiar with a collection domain (and have expertise) will be able to offer meaningful input and suggestions to novices. In some ways, the system here parallels Q&A sites that connect experts with novices (e.g. StackOverflow, Quora). It may be instructive to explore how these sites maintain a user base and address motivation.

Reflecting on reflection: Social learning in shared reflection. The shared reflection process we outline in this paper is similar to, but distinct from the collaborative reflection that we have seen in the past [44]: beyond focusing on a distinct domain (i.e. personal informatics data rather than work experiences), the shared reflection here emphasizes the shared task or responsibility of reflecting on the data at hand rather than simply asking for others for their experiences. In our study design, we made this reflection demand explicit by asking participants to reflect on the feedback as a separate, distinct part of the process. In so doing, we saw definite progress and change on the part of participants based on the feedback (e.g. Sarah, Esther)—that is, they developed new knowledge that was actionable [8]. We thus mimicked the kinds of learnings that we might expect from the Quantified Self Meetups as described by Choe et al. [12], and saw that the feedback was understandable in a practical way [47].

Yet the design of our shared reflection was imperfect in relation to the learning theories outlined at the outset. As described earlier, many participants would have liked to have had a more open "back and forth" with the people providing them with feedback. The limited one-directional flow of feedback meant that participants could not engage in the question asking and dialogue that underpins much of social learning [8][53]. Thus, our approach could most certainly be improved, again, by providing a mechanism to engage in dialogue with those providing feedback.

Challenge: Shared reflection is onerous. In our instantiation of the process, the weekly commitment seemed too much for some participants. Some did not reply promptly and needed to be reminded to provide feedback both to others and for their own data. In some ways, it is like learning in an elementary school—when learners are engaged, learning is an effective, efficient process. Yet here, it plays a secondary role in people's lives and is easily put aside if the work seems too much. As in Larry's case, since he felt he had reached his "ceiling" early, he might not be particularly motivated to engage deeply in the process. Sadly, it is people like Larry (i.e. with considerable experience) who would make a community richer by providing his insight to others.

The dependencies that shared reflection imposes make it very brittle. In our study, participants who did not write feedback would subsequently delay participants (who were to receive that feedback) downstream. Practical implementation needs to deal with this and the motivation issue as described above. This is not to say that it needs to engage people for a long term. It may well be the case that users could use a shared reflection for a short period of time—just enough to help them bootstrap their own reflection processes, and this would be enough.

Challenge: Privacy. The shared reflection process necessarily raises questions about data privacy, and about the circle of participants that one would feel comfortable working with. Unfortunately, we do not have clear answers here. The participants we worked with came into the study knowing that their personal data would be shared with strangers. Thus, it is possible that they may have chosen data sources that were not overly revealing, tailored their data in such a way to present their ideal selves, or self-selected in ways that we would not see this issue crop up. A related issue is how to practically implement this system with a circle of participants—does it work better or worse if the other participants are known to oneself? This remains unclear and warrants further study.

6. CONCLUSIONS

We have seen that shared reflection can work. People benefit by seeing their data from others' perspectives, and this can affect not only their collection practice, but also how they view their data, and themselves. Rather than relying on reflection to just "happen," shared reflection makes the process explicit, and demands engagement. This type of engagement is onerous though—for some experienced data collectors, the value is not evident if others cannot provide a new and meaningful perspective. But, for the vast majority of the participants in our study, they clearly benefited from the strategy. Deploying this strategy in a commercial project introduces many other challenges, and we look forward to exploring the motivation issue in future work.

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