What do Teens Make of Personal Informatics?

Young People's Responses to Self-Tracking Practices for Self-Determined Motives

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ABSTRACT

Personal informatics (PI) technologies allow users to collect data about aspects of their lifestyle like mood or step count. Though teens increasingly encounter and use such technologies, little is known about how they ascribe meaning to their own PI activities. We report a qualitative study of the PI experiences of eighteen teens (aged 14 – 17). Following a learning phase focused on interpreting PI data, participants chose a personal goal that interested them and a PI tool to track it for 4-8 weeks in everyday contexts. Participants proved to be competent, flexible users of PI tools, tracking a range of meaningful life factors, from 'worries' to 'exercise'; they valued learning about 'natural patterns' in their lives and were motivated to manage their emotions and evaluate whether they were doing the right thing. Our findings contribute to understanding how young people can engage in appropriation and interpretation of PI data – suggesting opportunities for educational interventions and design.

CCS CONCEPTS

• **Human-centered computing**; • **Empirical studies in HCI**; • **HCI theory, concepts and models**;

KEYWORDS

personal informatics, teen users, self-tracking, data interpretation

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1 INTRODUCTION

Smartphones and other consumer devices offer ever more ways to measure ourselves through quantifiable aspects of our lives like sleep, mood or productivity [43]. The proliferation of these tools has contributed to a new field within HCI: personal informatics (PI)[1]. PI users collect data about themselves to later reflect on and interpret [26]. As young people grow up with these technologies, it is important to consider the role PI could play in their lives. A recent report suggests that as many as half of UK adolescents have used a self-tracking technology to learn about their health, typically without adult support. [35]. Despite this, the studies have focused on adults and little is known about young people's motives and practices in using PI technologies.

The first wave of personal informatics research [26] focused on how users try to change their behaviour: for instance, by assessing the impact of PI on exercise and healthy eating [1]. The efficacy of such approaches has been challenged [20]. Furthermore, while the first wave evaluates a narrow set of activities as progress towards a predetermined goal [26], subsequent research has described more idiosyncratic and spontaneous motives for tracking, implicating personal interests, concerns and knowledge in the user's everyday life [28; 36].

Most prior work introducing personal informatics to young people in the context of schools has followed the framing of the first wave of PI research: evaluating how the PI practices promote a specific behaviour goal, such as increasing young people's physical activity [39] or decreasing hyperactivity [13]. Thus, unlike adult users of PI tools, young people in these school settings have had little agency over the course of their practice with PI tools, and limited opportunity to pursue their own motives.

A separate strand of work has used PI as a resource to facilitate curriculum-based learning in STEM subjects [11; 30]. After a brief period of teacher instruction, young people have proven to be competent users of PI tools: responding in ways appropriate to the learning outcomes [35; 45]. Though work in this strand may appear quite different to that focused on behaviour change, the PI data is still used as a stimulus for a particular set of predetermined responses: in this case, around the use of a target science concept. Less is known about the process by which knowledge develops and the extent to which it has become generalisable. While some studies have recognised young people's creativity in interpreting PI data to make personally meaningful insights (e.g. suggesting their grandad would benefit from their own PI practice [29]), work here remains limited. Most research to date has focused on adult-determined outcomes of young people's interactions with

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[1]PI can refer to the technological tool/system, the practices of a tool user, or to the study of these uses in HCI.

PI tools; less is known about young people's understanding of PI practices or the meanings they ascribe to PI data. What goals do young people pursue when provided with a personal informatics tool and what meanings do they give to their personal data? A richer description of the wider social practices in which tool use occurs is needed to better understand the "data work" [11] of young people.

The present study explores young people's personal motives in pursuing a self-tracking practice and the ways in which they understand these practices within specific social contexts. Rather than focusing on a curriculum area like mathematics, the present study examines the role of personal data in young people's everyday life: in what ways and to what extent self-tracking addresses their personal interests and concerns. We successfully engender openness and creativity, by first scaffolding discussion among peers about PI data in a classroom setting, then giving young people the opportunity to continue using PI tools in contexts of their own choosing outside the classroom. We focus on PI as a developing and social practice, showing how young people draw on their lived experience to motivate and reflect on their activities. By foregrounding aspects of the social context in which tracking occurs, we report on the individual experiences of young people with a wide range of concerns, interests, and perspectives. Our results suggest opportunities for design to better support young people's personally meaningful reflection on PI data.

2 RELATED WORK

2.1 Personal Informatics

In HCI, the term personal informatics (PI) has been used to refer to systems and practices which "help people collect personally relevant information for the purpose of self-reflection and gaining self-knowledge" [32]. PI technologies have rapidly developed with the proliferation of sensors in smartphones and other consumer devices [47], and self-tracking is becoming a ubiquitous part of our culture in the Global North [40].

PI tools have typically been adopted for self-improvement goals: defined in terms of optimisation of behaviours, such as physical exercise or internet browsing habits [24]. Most prior work has adopted behaviour change models describe PI tool use [32]. However, later work has challenged this linear framing and characterized the spontaneous nature of PI practices in the wild [42].

Whereas early work adopted behaviour change models to conceptualise the impact of PI technologies, later work has shifted the focus from self-improvement and behaviour change to self-knowledge and insight [19; 37]. Users have been found to appropriate PI tools for a wide range of idiosyncratic motives, from preparing for an exam to dealing with the loss of a loved one [44]; PI tools have allowed users to explore personal values and identities [10; 34] and to make personally significant insights [9].

2.2 Young people's Engagement With Personal Informatics

Given their ubiquity, it is not surprising that PI tools have been adopted by many young people. In a study of over a thousand 11 to 18 year-olds in the UK, 52% of survey respondents reported using digital health tools to measure, track, monitor and regulate their bodies and aspects of their daily lives including sleep, calorie intake, exercise, mood, heart rate, sleep patterns and menstruation [35]. Despite this, most consumer technologies are designed with adults in mind and research on young people is limited.

Work investigating how young people use PI tools has tended to implement behaviour change interventions in which young people track progress towards a quantifiable outcome, such as increased physical activity [14; 21] or weight loss [10; 44]. PI has often formed part of a system of extrinsic reward, bypassing the young person's own motives [19].

A second strand of research has implemented PI tools with a particular focus on data visualisations to scaffold young people's learning in a classroom setting. PI is reported to have successfully motivated young people in grasping a topic like bar charts or heart rate, encouraging them to feel a sense of ownership over their learning [25; 41]. Several authors have stressed the value of PI for supporting young people's ability to direct and personalise their learning: with PI data acting as a shared "object of inquiry" [6] through which they can "negotiate" [41] meanings. However, this work has been limited to the teaching of STEM concepts. To what extent can learning involve exploration or inquiry when the destination is fixed? The use of PI tools in this context relies heavily on the direction of the adult teacher or researcher, and it is uncertain whether PI enhanced the personal relevance and depth of learning. In one attempt to address this limitation [2], youth participants were given wearable physical activity monitors which they could take home, allowing them to experiment. The study aimed to support the situated learning of science concepts. This fixed outcome led to discordance between youth motives and understanding in their home context and the expectations of the science curriculum. The polysemous potential of PI data has here been reduced to a set of correct interpretations.

A few studies have allowed youth participants to use PI tools for their own purposes. This enabled participants to share ideas about aspects of their everyday life not anticipated by the researcher [24] and to reflect on the personal meaning of their experience [22; 34]. When young people have been enabled to draw on knowledge and interests from their lived experience, PI has contributed to a sense of self-determination, supporting learning about personally meaningful life factors like values [32], identity [42] and coping strategies [15]. Of course, not all PI practices are beneficial or healthy, and young people exploring these technologies may appreciate the support of an adult [35]. To support young people without restricting what they gain from their PI practice it is important to appreciate their concerns and motives [22].

Work with adult users of PI tools has recognised the role of social interaction in constituting the meaning of PI data [7; 27]. Sharing reflections on their own data can expand users' understanding by organising their thinking into a narrative and allowing the exchange of ideas. As Garbett et al. note, while PI has often been characterised as an individualistic practice, schools are social settings with the potential for the meanings of PI data to develop discursively [12]. Engaging young people as agents in personally relevant discourse can allow PI data to support meaningful insights [42].

2.3 Scaffolding PI Tool Use and Meaning Making

Vygotsky and Ilyenkov have criticised the view that knowledge can be transferred directly from a stimulus, such as a visualisation, to the mind of a learner [16; 47]. Derry [6] discusses a history lesson in which an image of Henry VIII is displayed on the whiteboard. The teacher asks students to discuss what they can tell about the man in the picture. Though the students seem to have been given freedom over their learning, lacking any basis on which to direct their inquiry, they are left to make trite comments like "He looks rich"; they do not contribute to the domain of knowledge in which the portrait is meaningful for the teacher, and into which the students are being enculturated. This limitation can be seen in much of the work introducing PI to young people: even studies pursuing learners' free inquiry as a research aim [2; 8] have not given sufficient attention to the process and context of meaning making. For Vygotsky, self-determination and creativity require that we master norms and constraints through which to situate our concepts [28]. Activity theory has explored how such mastery can be supported by involving artefacts to scaffold the course of a practice against a broader ideal/system of norms [21; 36]. In related work [4], young people were introduced to live physiological sensing and visualization (LPSV) technology to effectively support inquiry in science learning. Activity theory was used to illuminate salient aspects of the social context. Participants took part in semi-structured training with the technology before being enabled to explore life-relevant interests.

Activity theory supports and analyses the *development* of practice, rather than its *outcomes* [18]. Kow illustrates this by describing a gamer who interprets videos of his games to continually modify future gameplay and share his insights with other players [23]. As we gain mastery or understanding of a practice, we internalize norms and values that have been crystallized in the objects used in that practice [33], giving us greater agency in our choices; for example, in only needing the key signature to improvise with a band. The present study adopts activity theory as a guiding framework to plan and understand the social practices of young people introduced to personal informatics. In doing so we address the following questions:

1. What kinds of motives do young people pursue when engaging in self-determined personal informatics practices? (RQ.1)
2. How do young people interpret their own personal informatics data? (RQ.2)
3. Can introducing young people to personal informatics in a classroom context support them in having personally meaningful insights? (RQ.3)

3 METHODOLOGY

3.1 Participants

Young people (aged 14-17) at two comprehensive secondary schools in London, UK were invited, by their class teacher, to take part in a study about self-tracking apps and learning. They joined the study by returning letters of their and parental informed consent (approved by an institutional review board). Twenty-five students joined the study in total, eighteen of whom (9 female; 9 male – mean age 16) completed the study to interview stage. The participants who dropped out of the study, did so because their friends were not involved, they misunderstood the aim of the study or did not continue to show interest after the first session. Study sessions took place during tutor period[2] in a classroom at the participants' school.

3.2 Procedure

Given their possible lack of experience with PI tools [29], it was important to introduce participants to the concept of self-tracking and enable them to practice data interpretation in a semi-structured setting before they began using the tools by themselves. Following previous approaches [4], the study consisted of a learning phase in which participants were enculturated in the practice and an exploration phase in which they used the tools independently. Four thirty-minute scaffolding sessions (SS.#) supported participants in choosing what to track (RQ.1), interpreting data creatively (RQ.2), and sharing insights from personal data (RQ.3).

3.2.1 Developing Young People's Expertise in Personal Informatics. Scaffolding session one: Participants were introduced to self-tracking[3] as a diverse set of practices through screens of different self-tracking apps, shown on a digital whiteboard. The facilitator gave examples (from the Quantified Self website) of common and unusual self-tracking practices through visualisations of the users' personal data (such as socks owned, or kinds of things complained about in a month). Participants were prompted to discuss what the user might learn from the data. To help frame this discussion, and following prior work [42], participants were asked to consider the impact of different contextual factors such as the user having a disability or carrying out the self-tracking with their child. The session ended with a student discussion of what self-tracking could help them learn about in their own lives.

Scaffolding session two: Participants were offered cards with prompts of what could be tracked in a self-tracking practice: e.g. "How long I spent on an app", "Places I've been", "What I'm grateful for". These were informed by discussions in SS.1. Participants worked in groups to sort these cards by the impact they felt the factor could have on learning. Following an activity theory approach [8], this supported learning by mediating disagreement and discussion, and thus allowing participants to develop perspectives on the motives for self-tracking (RQ.1). Following this, participants each chose a factor they would be interested in tracking. The facilitator suggested a free commercially available app they could use to carry out this tracking (on a personal smartphone) or lent them an activity tracking tool (Fitbit Charge HR or Misfit Shine) to take home and use for the duration of the study.

Scaffolding session three: The lead facilitator checked whether participants had successfully downloaded a self-tracking app and advised participants on any technical issues they were having. For example, helping them to sync their Fitbit device with their smartphone, and showing how to adjust permissions on what aspects of their computer activity were tracked by RescueTime.

[2]The US equivalent is "homeroom".
[3]This was chosen as a more intuitive term than "personal informatics".

Table 1: Timeline of study activities

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9
SS.1	SS.2	SS.3	SS.4		One-to-one interviews			
	Independent self-tracking							

Table 2: PI apps and devices used by participants, what was tracked and whether they had used a PI tool at the time of the final interview or before the study (Though these signifiers do not fully capture the evolving practices).

	Tools used	Focus of tracking	Still tracking?	Ever tracked before?
P1	TapLog	Worries	No	Yes
P2	Fitbit	Exercise	Yes	Yes
P3	RescueTime, Fitbit	Online activity, steps	Yes	No
P4	Samsung Health, Daylio	Steps, mood	Yes	Yes
P5	RescueTime, HabitBull	Online activity, habits	Yes	No
P6	Daylio, Moves	Mood, steps	Yes	No
P7	Misfit, Toggl	Steps, sleep, time revising	No	No
P8	RescueTime	Productivity	Yes	No
P9	RescueTime, Taplog, Multi Log	Revision quality, anxiety level	Yes	No
P10	Fitbit	Exercise	No	No
P11	RescueTime, TapLog	Productivity, times distracted	No	No
P12	RescueTime, Strava	App usage, running	Yes	Yes
P13	RescueTime, Toggl	Productivity, time revising	Yes	No
P14	Daylio, MyFitness Pal, Health Mate	Mood, sleep	Yes	No
P15	Daylio, LifeMosaic, MyFitness Pal, Fitbit	Mood, steps	Yes	No
P16	LifeMosaic	Mood	Yes	No
P17	LifeMosaic, Daylio, Fitbit	Mood, steps, sleep	No	No
P18	Daylio	Mood	No	No

Scaffolding session four: Participants fed back to each-other about how their self-tracking was going and anything they were learning from their data. This allowed participants to share ideas about what they could track and gave additional opportunities to practice the "data work" [45] of forming insights (RQ.3) i.e. making explicit inferences they felt the data could warrant [5].

3.2.2 Independent Personal Informatics Practices. The scaffolding sessions supported participants in developing PI skills and allowed them to make an informed choice around what they wanted to track. After the scaffolding sessions, participants were invited to continue tracking something of their choice for a further four to eight weeks (until their interview)[4]; being encouraged to draw on their experience in the scaffolding sessions to explore whatever interested them. They were free to change the tracking focus or PI tool of choice at any point.

3.2.3 Data Collection And Analysis. Each participant took part in a one-to-one semi-structured interview. Interviews lasted around twenty minutes and participants were asked about what they had been trying to do and why, whether they noticed anything interesting or learned anything as a result of their tracking, and what their data meant to them or what it expressed about themselves and their life. All scaffolding sessions and interviews were audio-recorded and transcribed. Transcripts were initially inductively thematically analysed [3] and checked against hand-written notes from the sessions using NVivo: broadly focusing on participants' construction of meaning. Twelve coded categories were identified through repeated readings of transcripts. Data extracts within each category were then deductively analysed through an activity theory framework. This involved evaluating extracts in terms of *practices, social norms, settings, motives* and the *role of physical artefacts* (typically through references to personal data in the transcript and hand-written notes) [18], as well as the systems of concepts explored by the user and lived experience [46]. This process organized codes and extracts into five themes. The whole data set was reviewed again to check generalisability. Codes and extracts were shared within the research team and adjusted based on areas of disagreement in the analysis. The final themes broadly described user motives for engaging in self-tracking: confirmation of existing practice; judging and authority, behaviour change, evaluation of personal significance in everyday life, and supporting wellbeing.

4 RESULTS

Participants used fifteen self-tracking apps and devices for a broad range of motives (Table 1). Most participants were able to form and maintain a self-tracking practice and to also draw insights from the data they collected (RQ.2). Most changed or adapted the focus of

[4]This scheduling was dependent on the school timetable.

their tracking from the learning phase (RQ.1) to address everyday situations. Our findings suggest that PI practices supported young people in making personally relevant insights, as well as having broader effects on their everyday activities (RQ.3). The various overlapping modes of engagement for gaining insight with personal data, identified from the interview data, are described below.

4.1 Confirmation of Existing Practice

Most participants found that the data they collected confirmed rather than challenged their expectations. For some participants, this meant that the data they collected were trivial or unnecessary.

> I'm using my phone just what I'm using it for, so having the ability to track it, to me, it's fairly redundant. Because you know, I can see and I know I spend most of my time on a certain app. That's what I want to do. (P12)

P12 was already aware, at least qualitatively, of how he spent his time and did not feel PI would expand his self-determination. However, there were other instances when the external confirmation helped participants to maintain a practice. Indeed, these different modes of engagement could appear in the same individual.

> So I run, and we have a little saying with Strava: If it's not on Strava, it didn't happen. Like if you didn't track it and put it online, it didn't actually happen. It's like if this thing isn't recorded to me, if my usage isn't recorded, I can easily dismiss it. (P12)

While in the context of tracking productivity at home, PI data felt *"redundant"* to P12, in the context of running with friends, it formed part of ongoing discourse and shaped social norms and motivations for the practice. Despite this, many participants saw the data as *"unbiased"* (P7) and independent from their social practice. The apparent objectivity of the PI system could offer *"concrete evidence"* (P5) that could make participants feel *"reassured"* (P12) in what they were doing.

Whilst some users valued systems that offered simple reassurance, others sought out personal insight for its own sake or out of curiosity. Some participants explicitly preferred apps that let them *"see your own natural patterns of doing things"* (P4), rather than judging their data for them and making recommendations.

4.2 Judgement and Authority

Several participants suggested that PI tools could help maintain everyday practice around tasks that might be difficult or undesirable. Some characterised this as being like *the "gentle nagging"* (P3) or gaze of an authority figure like a teacher. Surprisingly, some participants wanted to imagine that their tool constrained their activity or held them responsible for sanctioned behaviour like completing schoolwork. PI could help them to judge whether what they were doing in their everyday activities (e.g. sleep or revision[5]) was *"right or wrong"* (P8).

> I find it helpful especially if I'm doing sports to just look at what it's doing. I want to see if I'm being healthy or not. If I'm making bad or good choices when I'm just in everyday life. Fitbit just makes that a lot easier. (P2)

The authority instituted by the self-tracking practice could also be used to legitimise some actions that would not otherwise be judged acceptable or appropriate. Tracking data allowed for some personal transactions to take place between time that had been "well-used" and time used in less authority-sanctioned ways.

> It also made me less guilty knowing that I spent for example two hours on revision. And then I can have a break and have fifteen minutes on social media. (P3)

While some participants portrayed their PI tool as a separate agent, others reported that it was them that had been given more authority through the PI practice. For example, P17 had been told by her parents about the importance of sleep and knew rationally that they were right but had been unable to act on this knowledge until she started self-tracking.

> I think it changed a lot [Shows Fitbit weekly sleep data] ... And then again slightly better. . . I don't know how to explain It. Before, I just couldn't say to myself that no you have to go to bed but the tracking made me do that. . . to say for myself that no I really have to go to bed and start sleeping. (P17)

As well as making insights about her sleep, P17 was the only participant to report lasting behaviour change. Self-tracking allowed some participants to make explicit what they were committed to doing. Although judgement had often ostensibly been deferred to the authority of the app, it was mediated by the user's own knowledge and interests.

> Working out, obviously you're tearing muscles so it's painful, but if you. . . have something to hold you to it, you're going to do it, and in terms of habits . . . it takes twenty-six days for a habit to be formed. So if you kind of promise yourself you're going to do it for twenty-six days, and it's like you have like a vision of "Oh, have you logged this yet?" (P5)

PI data could prompt participants to reflect on their activity and give reasons for what they were doing. P2 reported returning home from rugby training to find his step count *"was quite low, so what I thought is, it's my intensity"*. P2 drew on his own understanding of training intensity in interpreting his data and what he did "wrong".

4.3 Behaviour Change

Though few participants reported that self-tracking led to behaviour change, many framed their self-tracking through concepts consistent with behaviour change models of PI [26]. Participants often referred to *"correlations"* and other maths and science terms to explain the meaning of their data (with varying competence in applying them appropriately). Others used implicit deficit models as rationale for tracking behaviour change.

> I think when it comes to self-tracking, there's basically three stages: there's *understanding, control* and *change. Understanding* is you basically figure out what's wrong with you; *control* is controlling that, allowing yourself, just doing a few changes. . . (P6)

[5]Studying for an exam (UK).

Although P6 admitted he had not yet successfully implemented this model in his own self-tracking practice, using it to reflect on his activities during the interview allowed him to identify specific *"changes"* he was interested in making; for instance, around getting into the right mindset for homework. Participants sometimes described systems that were not fully developed or feasible, such as increasing their step count by two thousand steps every day (P15). This gap between espousal and practice suggests some participants may need more support to develop their ability to interpret data. The discourses participants engaged in during the study allowed them to experiment with scientific concepts to explain the significance of their experiences in relation to ideal forms of their activity [46].

Some participants carried out behavioural experiments: altering some aspect of their everyday routine for the purpose of assessing the impact. For example, going for a run (P15) or changing bedtimes (P7); these only tended to last a few days.

Despite not reporting sustained behaviour change, many participants saw their self-tracking tool as something which *"shows your progress"* (P4) and *"gives you something to aim for"* (P5). Participants often mixed motives related to behaviour change with other descriptions of what they found meaningful.

Conversely, some participants reacted against behaviour change framings of their activity, taking a critical stance on the behaviour *"expected"* (P14) of them. They characterised functions prompting behaviour change as controlling or *"irrelevant"* (P9). Some participants contrasted apps that just gave you instrumental *"information"* (P15) about a narrow goal with apps that prompted *"reflection"* (P15) and self-understanding.

> I think a lot of the apps are based on moving forwards... So, "improve your mood" rather than "accept your mood can vary". [But] Daylio will not say you've had a good streak if you've come downhill, but if you realise that and accept that to be the case and then think I can go on and it brings you a new sense of deeper ease with what things are like. (P4)

Some participants abandoned their PI practice because of contradictions between their own judgements and lived experience and what they were prompted to do by their tool. P10 abandoned his Fitbit after receiving notifications that he should take more steps when he felt he had *"already exercised well"*.

4.4 Evaluation of Personal Significance In Everyday Life

Several participants found that their practice *"helps you to learn more about yourself"* (P9) and *"[reminds you] of who you are"* (P16). Self-tracking offered some participants a chance to reflect on what was significant in their everyday life in ways that *"expressed different experiences"* (P1).

> It was 4.02 when I woke up! . . . I was like already not feeling so good and then. OK what day was it? [*Searching through Daylio data*] It says that I had a bad day, because I had homework to do. I read a lot, and I had to do sports that day. I ran and I hate running. (P14)

The self-tracking practice embedded participants' activities in systems of values and meanings. This allowed them to reflect on, share and potentially reorganised their experience [46]. Participants appreciated being able to adjust the units of analysis used in their self-tracking practice to adapt to their developing values and motives to give them *"new ways to think about"* their data (P5).

> I tracked my unproductive time and then I tracked things that were not productive but that I liked doing and are good for me, like relaxing. . . then I tracked different school subjects individually. And then. . . like a whole category of stuff that is good and that helped me towards my goal. . . like doing stretches before work. . . I realised a lot of my unproductive time was quite valuable to me, so I adapted it. (P13)

While participants could defer to their tool to judge whether they were engaging in an activity appropriately according to an implicit system of norms [5], they could also challenge such norms through wider evaluation against their life and identity.

> [RescueTime] makes you think, do I want to be someone who spends all their time on this site? (P8)

By offering representations of existing norms, PI tools could scaffold young people's creativity in reflecting on such norms with respect to their social context and everyday practices.

> You know it says OK my mood is good or bad. . . my sleep is good or bad. You can go back and see. . . with me my friend went [to another school] so of course it is bad because I care about my friend, but if maybe for another three days it is bad. . . I might do some social stuff. . . I might go to the cinema. (P16)

PI data could support learning by opening up wider topics and offering a "ticket to talk" [17; 38] for young people to discuss issues of personal significance they might otherwise find difficult to broach. Participants' ability to assess data critically developed over the course of the scaffolding sessions as they engaged in discourse around the social context in which it could be collected (RQ.3). P14 came to a scaffolding session (SS.4) having tried the *MyFitnessPal* food tracking app. The scaffolding session setting allowed participants to explore ideas around food tracking and discuss social norms around dieting and eating disorders. Three participants subsequently gave critical accounts of food tracking in interviews; for instance, regarding the *"guilt"* (P18) and *"wrong ideas"* (P14) they could prompt.

The scaffolding session and interview process acted as a powerful setting for PI to support personally relevant learning, potentially helping participants make better informed choices in the future.

> Because if you start really really caring about what you eat, you end up being obsessive, not eating anything. You know, it's important to eat what you enjoy. . . I eat bad a lot of the time but I'm at least more aware of it now and I might go easy on it but I'm not that fussed. (P12)

These participants were able to develop a new relationship to the perceived authority of their data, and through this process to gain self-knowledge about their everyday practice.

4.5 Supporting Wellbeing

Most participants discussed mood or emotions in connection with their self-tracking. While it did not tend to change their behaviour, for some participants PI proved therapeutic[6] in prompting reflection that reframed emotions or behaviours they judged bad.

> I have a science test in two weeks and... I feel really really stressed about it... [*Shows Daylio data*] You can see every single day this week I've done homework because I've been revising so much for it. But I think when I put it down [on Daylio] I just realise how much I've been revising; I just kind of think to myself "It's fine!" (P14)

The data helped the user to externalise negative judgements and build a new relationship to them; for instance, by *"figure[ing] out how much time I waste [worrying]"* (P1). By attributing meaning to data artefacts, participants were able to work through their experience and add granularity to their perspective on a problematic situation [46].

> Toggl... was very calming actually... Hav[ing] a physical record [of my activities] there, you get yourself into a position to have your stress at the right level... [When] you're like, "Oh my god, what if I've not done anything!" To really just have a number there and be like "I have!" That's quite good. (P13)

By explicating and validating some aspect of the user's everyday actions and emotions, the self-tracking practice was able to act as a ground for self-understanding. One participant used *Multi Log* to develop a 1 to 5 scale for tracking her anxiety. This process helped her discern the quality of individual episodes of anxiety; such knowledge brought a sense of empowerment.

> Even if I don't get up and do anything, I still feel like it is this kind of anxiety so I know what it's like, and I can watch a video online or just maybe do some drawing. So even if it's not a big correlation of 'this causes this', you still know you have certain choices and you can remind yourself because you're actually sitting down and tracking it. (P9)

Personal informatics enabled some participants to report feeling a sense of self-determination over some aspect of their life through the personal knowledge they brought to bear upon it in practice. Their data provided an external artefact to reframe emotions that were negative, confusing or overwhelming. Notably, some participants had internalised [47] concepts from their self-tracking practice to apply them to everyday activities when they were not using the tool.

> You get to know, OK this is a 2 out of 5 so I can watch one of my favourite YouTube channels and I'll be fine soon; or it is a 5 and I need to lie in bed, and I can forget about work. (P9)

Though P9 had largely stopped using Multi Log, the categories she developed on the app continued to act as a unit of analysis, mediating her response to her anxiety.

[6]In the psychoanalytical sense of personal understanding rather than the clinical sense of treating symptoms.

Some participants implied a link between their personal use of technology and their wellbeing. They contrasted the impact of low-value or *"not healthy"* (P15) activities like social media and watching YouTube with high-value or *"better for me"* (P18) activities like painting or spending time with friends (P14).

> Sometimes you look at your screen time and you see you've had like eight hours on the weekend and it's like really freaky and you want some distance. It's just not healthy for your body or your mind. (P15)

PI data could implicate many aspects of young people's everyday social practices which they found it helpful to reflect on, both independently and in expressing their experiences to others.

5 DISCUSSION

This study aimed to investigate what kinds of motives young people pursued when directing their own PI practices (RQ.1), how they interpreted PI data (RQ.2) and whether this process could be successfully implemented to support them in making personally relevant insights (RQ.3). Participants developed self-tracking practices through a diverse set of concerns, values and prior experiences. This section identifies some opportunities and challenges for future work interested in designing PI tools and interventions for this group.

5.1 Developing Polysemous Motives and Meanings

As their experience of PI developed, participants often switched between self-tracking tools and found new ways to appropriate them to meet their evolving motives. Others found the information they gathered to be unsurprising, trivial, or contrary to what they felt was already true. This generally led to abandonment.

Some saw PI as an opportunity to pursue and monitor change, making their use consistent with behaviour change models of personal informatics [26]. These participants began to appropriate scientific concepts from the PI system or their own practice as units of analysis for aspects of their lived experiences [46; 47]. Even familiar everyday concepts like "worry" (P1) and "anxiety" (P9) could develop through PI: expanding the granularity of the young person's experiences, including when they were not using the tool.

Following an activity theory orientation, we note that by making some aspect of the users' activity into an external artefact (visualisation) [33], the data afforded a wide range of interpretations (RQ.2). This could involve operational judgements, like whether they were using their homework time well (P5), or wider evaluations that implicated emotional experiences like parting with a close friend (P16). The self-tracking could provide a system of personal accountability by which young people could "allow" themselves time on Snapchat (P3) or a lie-down (P9). Other participants just appreciated seeing their "natural patterns" (P4) and learning more about themselves.

Participants stressed that their PI tool should be able to adapt to their developing concerns, rather than trying to fix the meaning of their data (P15), or telling them what to do (P14) or what is important (P4). Designers of PI tools and practices for this user group should prioritize flexibility: allowing users to set and modify their tracking focus and the units of analysis (metrics) by which it is framed.

5.2 Exploring Norms and Ideals

Following Weiner [48], we found that participants "borrowed authority" from the PI system to add weight to decisions or personal judgements. Žižek uses the example of Watson to Sherlock Holmes and Hastings to Hercule Poirot to describe the "big Other" we all imagine watching over us [49]. Watson and Hastings offer the sensible perspective of society at large. They evaluate the detective's actions and offer common wisdom but lack the creative energy to solve the crime. The participants in our study often characterised their self-tracking tool as the voice or gaze of a teacher, policeman, or another representative of the social order. In speaking for the adult world, the data provided them with security and a sense that they were doing the right thing, giving them the freedom to draw new insights. As Pantzar & Ruckenstein argue [31], "numbers and data visualisations provide a stable frame of reference that stands in opposition to subjective forces of knowledge formation." In playing with their data, young people reorganised their experience to form a new relationship to their routines, experiences, identities and future activity [46; 47]. For example, viewing a weekly reduction in YouTube use on RescueTime as preparation for university (P8).

Our findings contribute to research considering the *data work* of users in "making data visualisations accountable to local activities and events" [11]. The social norms committed to by the user in interpreting their data implicated many aspects of their social context [45], including where they were, who they were with, whether others were using the tool, and what others thought about their wider practice. The self-tracking practices created accountabilities (some welcome, some not) and validated young people's judgement. Perhaps the most meaningful distinction to be drawn from adult users of self-tracking technologies is in the reconciliation of still-forming personal identities in a world in which what is considered good or desirable is still framed by adults and not always negotiable. When personal realisations fit with the framings of adults, such as being productive in their studying, young people could find validation in their tracked activity (P3).

The authority of the PI tool also raised ethical implications in relation to the automated recommendations it gave users. Participants tended to react disagreeably to tools that directed them to take a particular course of action (such as a set number of steps), but some put trust in the tool and relied on it to determine what future action was acceptable. As P18 noted, such uses could introduce the risk of developing unhealthy habits or promoting bad health decisions, as related to diet. The risks of food tracking for young people have long been recognized [40], but further work is needed on how to support the growing number already engaging in such practices of their own accord [35]. Our findings contribute to work suggesting that schools could play a valuable role in supporting young users [9]. Addressing RQ.3, our findings illustrate how PI practices can create spaces for youth to explore health topics and other social issues implicated in PI data. The semi-structured collaborative scaffolding sessions [33] allowed for the facilitator to offer guidance, ask questions and highlight potential risks. Contradictions between the user's lived experience and the meanings or systems of norms they attributed to the data could prompt reflection and re-frame their relationship to the practice, potentially shaping future choices.

5.3 Supporting Social And Emotional Learning

The dominance of mood tracking in our data spoke to the importance of emotion in young people's lives [37]. Following Vygotsky's account of lived experience, or *perezhivanie* [46], we note that emotion did not just colour participants' existing experiences but formed part of a process that restructured these experiences with respect to past experiences and current drama, for example in reflecting on how an inconsistent sleep routine was impacting their wellbeing by affecting their attitude to revision (P7) or how they were glad to have a low mood as it showed that they valued a friend they'd been separated from (P16). For many participants, the "chaos" (P6) of their emotions was something that they appreciated support in dealing with. The data could turn the "ambiguity and messiness into something manageable" [31]. For some, PI data provided scaffolding, helping them regulate their emotions. Self-tracking put things into scale (P15), letting young people weigh up the significance of their experiences. There are opportunities for future work to explore how PI can support young people's social and emotional learning in semi-structured contexts, such as mentoring or relationship, sex and health education (RSE)[7].

Narrative meaning making may play an important role in adolescents' social and emotional learning [30]. We build on prior work on the role of narration in interpreting PI data with young people, as a way to enhance their sense of agency [42]; supporting awareness of norms and influences implicit in their life. Data-mediated discourse proved a powerful technique for meaning-making. We follow prior activity theory approaches [4] in noting the positive impact of a learning phase involving semi-structured collaboration with peers in developing young people's skills for this process. As Pantzar & Ruckenstein argue, when the framing of self-tracking is widened from the individualistic rationalism assumed by much design in PI to the developing social practices into which PI tools are appropriated, "the metrics of life promoted by self-tracking can generate new types of discussion wherein encounters with the data and culturally shared understandings can inform each other" [31]. This is a tentative process which broke down when young people took their activity to be valorised by an extrinsic standard beyond their control.

6 CONCLUSION

Research in HCI seeking to introduce PI to young people has tended to focus on prescribed outcomes, with expectations for the young person around acquiring curriculum content or behaviour change. Our findings show that young people can draw meaning from their practice that is self-determined and related to their own concerns (RQ.1). Our scaffolding sessions helped to develop a view of PI as polysemous and supported participants in developing a critical stance to the norms and ideals they found in their lives (RQ.3). By testing and appropriating PI tools to pursue personal interests, participants developed skills and concepts they could generalize to multiple domains and situations (RQ.2). This highlights the importance of working from the young person's perspective: recognizing the different spheres they live in and the differing norms which govern them.

[7] New UK curriculum promoting young people's self-efficacy to make informed decisions about their health, relationships, and wellbeing.

Our participants varied in the extent to which they found tool use beneficial or conductive to self-determination. We argue that a key determinant here is in how the practice framed tool use; for instance, given too much freedom users felt the data was trivial or confusing, but with too much structure, they felt the technology was trying to control them, or found it harder to interpret their data creatively. The PI practice needed to offer enough constraints to orient the user: as a stable ground for their judgements, but enough freedom to be adopted into the situations they experienced. Conversely, we report on PI practices which surpassed the ephemera of instrumental goals to be embodied by young people in ways that draw meaning from the whole of their life and identity. This suggests the potential of PI to support development and learning in areas outside of STEM, such as sleep hygiene, time management and well-being.

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