Design and Field Trial of Datarium: *Representing Slightly Changing Digital Illustration Based on Personalized Tracking Topics*

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Empowering individuals through a personalized self-tracking system that provides a deeper understanding of themselves is important for helping them remember to work towards their personal goals. To pursue this research opportunity, we designed and implemented six Datariums that record and visualize tracking topics as personalized digital illustrations, using a five-week collaborative design process with six participants. In addition, a two-week field study was conducted to investigate the user experience of Datarium. Through this study, we found that encountering personal records via changes in the visual state of representations motivated users to record. Moreover, this approach provided a sense of security because users themselves determined how their records were visualized in the digital illustration. Findings suggest the need to consider the design of self-tracking systems that support the recording of personally meaningful information and present these records in more immersive ways.

Keywords **–** Co-design, In-field Study, Personal Data, Personal Visualization, Self-tracking System.

Relevance to Design Practice **–** This research offers valuable insights for design practice by proposing a collaborative approach to self-tracking tools that integrate personalized tracking topics and metaphoric visualization methods. By exploring metaphorical visualizations and unaware-tracking opportunities, it provides guidance for creating emotional connections and user-centered designs in personalized data visualization and self-tracking systems.

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Introduction

Personal tracking systems have been widely adopted to monitor behaviors such as drinking, smoking, sleep patterns, and clinical conditions including depression and autism. While early systems primarily focused on behavior change or clinical outcomes, recent research has emphasized self-tracking as a means for self-awareness and personal understanding. This shift is articulated in the Lived Informatics framework (Li et al., 2010), which conceptualizes self-tracking as a five-stage process—preparation, collection, integration, reflection, and action. The framework highlights that effective self-tracking extends beyond data collection to include meaningful preparation, interpretation, and integration into everyday life.

How users reflect on their data is strongly shaped by how that data is represented, a phenomenon described as the representational effect (Zhang & Norman, 1994). In response, the notion of Data Humanism has been proposed to foreground human experience, context, and meaning over abstract numerical representations (Lupi, 2017). Subsequent work has shown that data representations grounded in personal narratives and lived contexts can stimulate imagination (Park et al., 2025), support sense-making (Rapp & Cena, 2016; Rapp et al., 2018), and help users uncover meaningful insights embedded in everyday data (Park et al., 2025; Strömel et al., 2024). Conversely, data representations disconnected

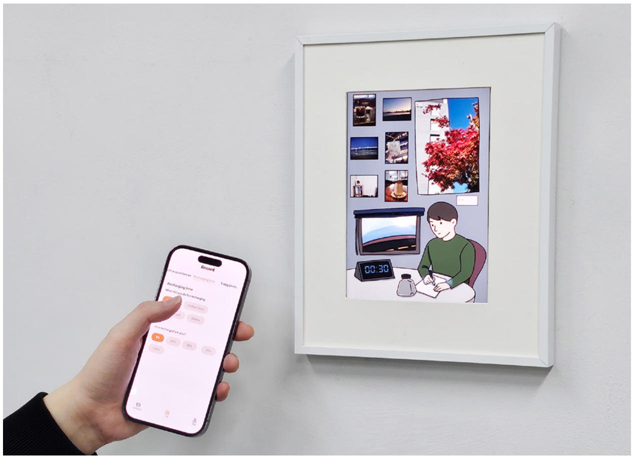

Figure 1. Datarium Frame presenting personalized digital illustrations.

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from users' lived experiences often fail to sustain engagement or generate meaning (Rapp & Cena, 2016). Together, these studies underscore the importance of reflecting personal context and lifestyle in the design of self-tracking systems.

Although meaning-making is often associated with the reflection stage in the five-stage model, prior research suggests that reflection is distributed across the entire self-tracking process—including decisions about what to track and how to represent it (Thudt et al., 2018). In particular, the preparation stage plays a critical role in shaping subsequent engagement and interpretation. Epstein et al. (2015) identified key barriers at this stage, including difficulties in selecting appropriate tools and deciding which aspects of one's life are worth tracking. Existing approaches have sought to address these challenges by recommending tools (Lee et al., 2022), enabling customization of tracking parameters (Kim et al., 2017), or supporting goal setting (Woźniak et al., 2020). However, preparation has often been operationalized as a technical selection rather than as a reflective process of deciding personally meaningful tracking topics.

Sangsu Jang is an assistant professor in the College of Art and Technology at Chung-Ang University in South Korea. He received his Ph.D. in Human–Computer Interaction and Design, focusing on how digital technologies can support users' self-recording behaviors to enrich self-reflection and everyday well-being. His research explores personal informatics systems, including journaling and tracking applications, as well as everyday object-based reminders. He investigates how systems can prompt users to record their experiences through reflective questioning, and how the collected data can be represented in alternative, expressive forms of data visualization. His work aims to design interactive systems that foster meaningful engagement with personal data and support long-term reflection in daily life.

Jin Young Moon is a Ph.D. candidate at Ulsan National Institute of Science and Technology (UNIST) in South Korea. Her research focuses on designing interactive products and systems that support instant messaging communication among intimate groups over distance. She investigates how digital messages can be leveraged to sustain and amplify intimacy in everyday communication. Her work particularly explores the role of physical interfaces and materiality in shaping communication experiences, aiming to facilitate more natural initiation and termination of conversations. Through this approach, she seeks to enable lightweight, socially nuanced interactions that better reflect the dynamics of close relationships in everyday life.

Nanum Kim is an integrated M.S.–Ph.D. student at UNIST. Her research explores how personal digital data can be meaningfully experienced through interactions in physical space. She investigates ways of treating everyday digital records—such as photos, moods, and personal archives—as design materials for creating interactive artifacts. By bridging digital information and tangible environments, her work enables people to engage with their personal data in more reflective, embodied, and everyday ways. Her research interests include human–computer interaction, tangible interaction, personal informatics, and the design of interactive systems that connect digital data with physical experiences.

Hwajung Hong is an associate professor in the Department of Industrial Design at KAIST and leads the DxD (Data, Interaction, Design) Lab. Hong's research in human-AI interaction focuses on developing systems to improve human-data interaction across diverse settings, such as healthcare and education. Her work aims to enhance the ways people interact with and through data and AI, with a particular emphasis on creating inclusive technological experiences for individuals with special needs.

Young-Woo Park is a professor in the Department of Design at UNIST, where he directs the Interactive Product Design (IPD) Lab. His research resides at the intersection of Human-Computer Interaction (HCI) and Product Design, specifically highlighting the significance of 'physicality' in everyday interaction. Recently, his team has explored using personal data from AI services as a design material to create interactive artifacts that enable tangible exploration of digital archives. His approach also investigates the embodiment of ephemerality as a method for future tangible interaction. His academic service includes serving on the Technical Program Committees for ACM CHI, DIS, and TEI. Furthermore, he demonstrates the practical impact of his research through prestigious international design awards, including the iF Design Award, Red Dot, and G-Mark.

Importantly, even individuals without prior tracking experience often possess curiosity about their everyday life (Rapp & Cena, 2016). We frame these as unaware tracking opportunities—aspects of everyday life that users do not initially consider trackable, but which can become meaningful sites for reflection once surfaced. A small number of studies have begun to explore ways of eliciting such topics through reflective questioning, extended discussion with researchers (Park et al., 2025), or engagement with personal everyday objects (Karyda et al., 2020) These works also suggest that the significance of tracking topics is closely tied to how data is represented. Representations that align with users' lived environments—such as data embedded in everyday objects—can foster richer and more sustained personal reflection (Karyda et al., 2020).

Regarding visualization of personal data, beyond conventional statistical visualizations, alternative approaches to data representation have explored physical (Karyda et al., 2020; Khot et al., 2017; Lee & Hong, 2017), artistic, and metaphoric forms (Froehlich et al., 2009; Jang et al., 2021; Murnane et al., 2020; Viégas & Wattenberg, 2007). Such representations allow users to embed self-authored meanings and autobiographical associations into their data, transforming abstract records into personally interpretable cues. For example, Murnane et al. (2020) demonstrated that framing physical activity data within a fictional narrative increased emotional engagement and motivation. Similarly, Park et al. (2025) showed that AI-generated images based on personal data can encourage users to interpret their data in ambient and open-ended ways. These approaches suggest that metaphoric and narrative visualizations can support meaning-making by fostering emotional resonance and personal interpretation (Nam & Kim, 2011; Orth et al., 2018)

Taken together, prior research highlights two underexplored design spaces in personal informatics: supporting the emergence of unaware tracking opportunities and enabling representations that reflect users' personal contexts and lifestyles. To explore these spaces, we developed Datarium, an exploratory self-tracking system comprising a mobile application for recording personalized tracking topics and a digital frame that displays user-defined, ambient visual representations of the recorded data. This study focuses on users' experiences of identifying personalized tracking topics and engaging with their visual representations in everyday life, rather than on the usability of the mobile interface.

Although Datarium employs alternative and narrative forms of data representation, it is not designed solely for non-expert users. Prior work has shown that even experienced self-trackers encounter challenges in creating and interpreting data visualizations (Choe et al., 2014), and that narrative representations can support data interpretation for both expert and non-expert audiences (Shao et al., 2024). Accordingly, Datarium is intended not as a simplified visualization tool but as a system that supports personal reflection through data embedded in everyday contexts.

The key contributions of this paper are as follows:

1. Datarium, an exploratory self-tracking system that enables users to define personally meaningful tracking topics and represent them through ambient, metaphoric visualizations.

2. A collaborative facilitated elicitation process that supports the emergence of previously unrecognized tracking opportunities through reflective engagement with users' everyday lives.
3. Empirical insights and design implications from an in-the-wild study on how personalized, ambient visual representations shape reflection, motivation, and perceived privacy in everyday contexts.

Related Work

Personal Tracking Systems for Self-Awareness and Understanding

In recent years, new research trends in self-tracking have emerged in the HCI and design fields, focusing on systems that support recording for self-awareness and self-understanding. This new perspective has allowed users to view self-tracking as a tool for better understanding oneself, self-identification, and self-inspiration, rather than solely for behavioral change or record analysis. From this viewpoint, various terms have emerged, including *documentary information* (Elsden et al., 2017), *lived informatics* (Epstein et al., 2015) and *data humanism* (Lupi, 2017). They commonly emphasize the significance of data from an individual's standpoint, the cultivation of self-awareness through record-keeping, and the acquisition of intriguing and meaningful insights. In the pursuit of implementing a self-relevant tracking system that holds significance for users, previous researchers have undertaken the task of recording data, despite its potential time-consuming and cumbersome nature, to promote self-awareness (Choe et al., 2014; Li et al., 2012). For example, through the utilization of manual tracking methods, the importance of acknowledging the agency (ability to make choices and act based on the collected information) of records has been corroborated (Ayobi et al., 2020; Murnane et al., 2016). In addition, a range of research efforts have been undertaken to bolster users' self-awareness through self-tracking. The primary emphasis of these studies has revolved around personalization. For example, some applications (Ayobi et al., 2020; Kim et al., 2017) provided customization options for tracking topics, parameters, and schemas to support personalized tracking.

Furthermore, one study has proposed ways to help users choose goals that align with their daily lives, taking into account contextual factors such as life events (Woźniak et al., 2020). Additionally, there have been efforts to recommend suitable self-tracking tools by assessing individual users' needs (Lee et al., 2022). These endeavors provide insights to help users find suitable tracking tools, goals, or preferences, thereby promoting a personalized approach to data recording. However, it remains challenging for users to identify what is meaningful to track for themselves (Epstein et al., 2015). Users often have latent or unarticulated needs tied to their everyday lives, which makes it difficult to recognize certain experiences as potential tracking topics (Rapp & Cena, 2016)

Alternative Visualization for Meaningful Data Representation

The "representational effect" described by Zhang and Norman (1994) highlights how different isomorphic representations can influence cognitive behavior. Many studies note that traditional graphical and numerical visualizations may challenge or demotivate (Coşkun & Karahanoğlu, 2022; Huang et al., 2015; Lupton, 2016; Viégas & Wattenberg, 2007), prompting interest in alternative, qualitative representations that go beyond statistical charts to present data meaningfully (Abtahi et al., 2020; Elsden et al., 2016; Lupi & Posavec, 2016; Snyder et al., 2019). This underscores the need to explore everyday visualization approaches that enhance users' perception of data. Pousman et al. (2007) introduced causal information visualization, which emphasizes personally relevant data sets, broader accessibility, and less task-oriented activities. Similarly, Snyder (2017) evaluated vernacular visualizations, which are information visualizations designed by the public, who draw upon their local or cultural knowledge to convey information visually. For this, Active research utilizing metaphoric representations in data visualization has the potential to create an emotional connection (Lin et al., 2006) between users and data. For this, there were attempts to represent personal tracked data and to provide users with customization options to determine how their data is presented. For instance, Trackly (Ayobi et al., 2020) offers pre-set visualization themes that users can select to present their data, along with mapping tracking parameters to visualize variables such as color. In addition, DataSelfie (Kim et al., 2019) allows users to combine and express visual representations based on personalized, unique question options by directly writing questions for recording, then drawing corresponding expressions on the canvas using the recorded answers. Another approach to alternative data representation involves metaphoric representation. For instance, Consolvo et al. (2008) introduced UbiFit Garden, which used virtual garden metaphors to encourage physical activity, while Froehlich et al. (2009) developed UbiGreen, which promoted eco-friendly behavior through metaphorical representations. Such approaches often integrate aesthetics, using artistic techniques to enhance analytical reasoning and contextualized understanding (Viégas & Wattenberg, 2007). Also, it could enhance interest and engagement (Redström et al., 2000; Snyder et al., 2019) through visualized results, compared with simplistic graph-based expression methods.

Summary and Derived Research Questions

Collectively, research in personal informatics has highlighted the potential of participatory approaches to support lifestyle-based, subjective interpretation in self-tracking systems. Prior studies have explored alternative data representations that go beyond preset approaches by allowing users to define visual elements (Kim et al., 2019), incorporating situational contexts in everyday environments (Bressa et al., 2022), or leveraging familiar objects in personalized tracking experiences (Karyda et al., 2020). However, these efforts have largely examined such elements in isolation, leaving limited understanding of how users can integrate the discovery of personally meaningful tracking topics, the construction of corresponding visual representations, and the everyday encounter with these representations into a coherent experience. In particular, the experiential effects of engaging with personalized, ambient visual representations—such as surfacing previously unconsidered tracking opportunities, sustaining engagement, and supporting everyday reflection—remain underexplored.

To address this gap, we pose the following research question (RQ): What experiential effects emerge when personal tracking data is represented through personalized, user-authored ambient visual displays? More specifically, we examine:

- **RQ1:** How do people come to recognize previously unconsidered personal tracking opportunities through engaging with personalized visual representations, and what kinds of insights emerge in this process?
- **RQ2:** How does encountering one's personal records through digital-illustration—based ambient displays shape users' experiences of engagement, reflection, and interpretation in everyday context

To answer these research questions, we conducted a five-week collaborative design and implementation process for Datarium, followed by a two-week in-the-wild field study (Figure 2). The study consisted of two stages. First, a one-week concept derivation stage included a pre-diary study and individual co-design workshops to identify personalized tracking topics and corresponding visual representations. This was followed by a four-week refinement and implementation stage, during which the system was iteratively developed in response to participant feedback. Finally, a two-week field study examined participants' everyday experiences with Datarium.

Research Process

For designing the Datarium system and evaluating its user experience, we used two different methods: 1) collaborative design & implementation, and 2) field study.

Collaborative design and implementation: This process aimed to collect personalized self-tracking topics and visual representations in the form of digital illustrations, which constitute key elements of the Datarium system for each participant. To this end, we adopted a collaborative design approach, engaging participants as experts in their own lived experiences to derive design outcomes grounded in their insights and knowledge (Sanders & Stappers, 2008).

We conducted individual co-design sessions for each participant rather than group workshops to foreground each participant as an expert in their own life and to elicit their personal contexts more effectively. Focusing on individuals allowed us to attend closely to the nuances of their lived experiences, which might be diluted in group settings. In addition, when working alongside unfamiliar others, some participants—particularly those who are more reserved—may feel less comfortable self-disclosing, potentially limiting the richness of the personal context they share.

The collaborative approach aligns with prior work demonstrating the effectiveness of co-design in developing self-tracking systems that reflect personal contexts and lived experiences (Bressa et al., 2022; Snyder et al., 2019).

Field study: Following the collaborative design and implementation of the Datarium, we conducted a 2-week field study to investigate participants' experience using Datarium. Specifically, we aimed to explore two key points: 1) how users perceive and accept the integration of the Datarium Frame into their daily spaces; and 2) what kind of experiences are conveyed through the recording of personalized tracking and encountering past records through visual representation (in digital illustration form) displayed in the Datarium Frame.

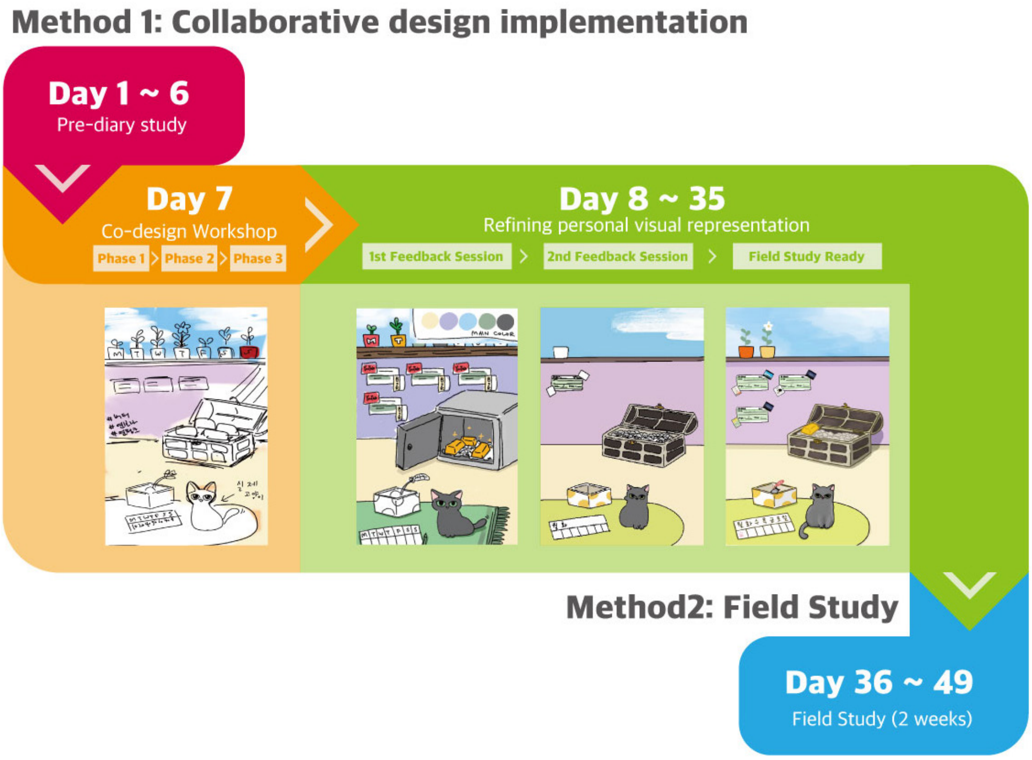

Figure 2. Five weeks (35 days) **collaborative design process of Datarium's visual representation.**

Participants: To recruit participants, we distributed flyers and used local social media services featuring a QR code linking to a registration form with a brief survey about their previous tracking experience. Finally, we selected six participants (P1 to P6) who keep records of themselves periodically for more than a year and use more than two self-recording methods (e.g., Paper diary, Apple Watch, or Mobile App). We acknowledge that the sample size of our study is small. Rather than aiming to quantify or generalize visualization elements, we intentionally adopted an in-depth qualitative approach with a small number of participants to closely examine individual practices and collaborative design processes (Gaver et al., 2007; Pinder et al., 2025; Pousman et al., 2008). This approach enabled us to focus on each participant through individual workshops. Through this focused engagement, we captured rich, context-sensitive insights into participants' unique life contexts and nuanced experiences.

Their demographic information is as follows.

- P1 (26, Male) AI-related researcher. He has recorded monthly study hours and monthly expenditure records on paper and impressive music albums on social media. Previously, he made a YouTube playlist of his favorite music, kept a diary, and recorded his compositions.
- P2 (51, Female) Director of City Welfare. She is recording her health metrics (e.g., skeletal muscle mass) using an in-body device (a body composition tracking device) that syncs with the app. She previously also kept a journal of her children's growth.
- P3 (19, Female) University freshman student. She is writing down her studies, daily schedule, impressions, and exercise time on paper. Previously, she recorded simple but necessary missions, such as drinking water and taking vitamins on paper.
- P4 (30, Male): A graduate student in the materials science and engineering department. He organizes his expenses in Excel and writes down his recent feelings and thoughts in a 10-line paper diary.
- P5 (25, Female): Display-related researcher. She wrote various entries in a diary, such as descriptions of delicious food, unique or cute things she found, and her emotions for the day. In addition, she took a photo of the beautiful sky and recorded her exercise using the Apple Watch.
- P6 (34, Female) Teacher at a special school. She uses various notebooks to record tracking, such as short (four to six lines) daily diaries, daily happy moments, movies, or books. Furthermore, she recently counted daily steps via a smart band (for viewing, not recording).
- R1-R3: Additionally, in the collaborative design process, three HCI researchers (R1: Moderator; R2: Artist, and R3: Visual Drawing Coder) with specialized expertise were involved in the project.

Method1: *Collaborative Design Implementation*

Pre-Diary Study

To prepare for the workshop, we conducted a pre-diary study (days 1-6) in which we asked participants about their lifestyles and environments. This study helped us gain insights into the participants' life contexts and identify potentially meaningful tracking by examining their daily lives, which we used to prepare for workshop sessions. To conduct the pre-diary study, we used the Datarium mobile app and presented participants with a pre-diary screen (Figure 3), which enabled them to answer questions about their daily lives on their mobile devices.

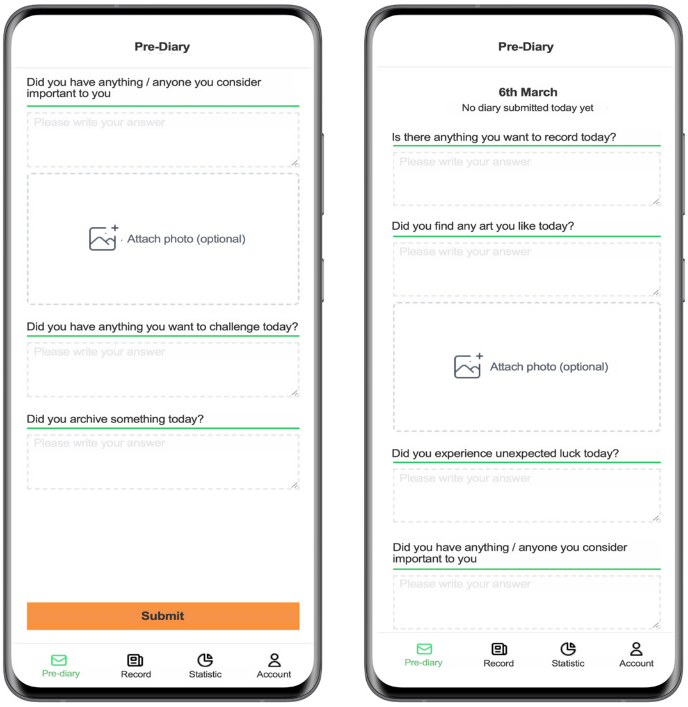

Figure 3. Material for pre-diary study.

Co-Design Workshop

Following the pre-diary study, we conducted co-design workshops for each participant, each lasting approximately 2 hours and involving R1, R2, and R3. During these sessions, we derived each participant's tracking and initial sketch for visual representation (Table 1) through a three-phase process: 1) uncover personalized tracking based on participants' daily experiences, 2) map tracking for visual expression, and 3) finalize the initial personal sketch of visual representation (digital illustration concept). Each researcher played a distinct role throughout the workshops. R1 served as the moderator, facilitating discussion and guiding the overall flow of the workshop. R2, an artist, translated participants' verbal descriptions and emerging ideas into real-time rough sketches, helping externalize abstract visual metaphors and aesthetic preferences. R3 acted as a visual coder, assessing the technical feasibility of the proposed visual expressions and ensuring that the finalized concepts could be implemented consistently within the Datarium Frame system.

Phase 1. Uncovering personalized tracking topics based on participants' daily experiences: The first phase aimed to obtain personalized tracking topics and parameters, which took approximately 40 minutes. To achieve this objective, we designed a questionnaire based on the responses from the pre-diary study and provided a mapping card (Figure 4a) containing four segments for recording one's own tracking, parameters, visual expression, and visual variables. In this phase, we asked the participants to fill out the first two segments, i.e., tracking and parameters. In this process, R1 asked questions about the participants' lifestyles based on their responses from the pre-diary study. The participants answered questions about their lives, and if they found any interesting tracking and parameters, they wrote them down on the mapping card. At the same time, R2 attentively listened to participants' responses and began analyzing underlying visual metaphors and artistic preferences embedded in their narratives. During this process, the researchers also suggested some potential tracking if they noticed anything while listening to participants' answers. By iterating on the above process, we derived multiple mapping cards, and we asked the participants to select the final tracking they wanted to record.

Phase 2. Mapping tracking to visual expression: In the second phase of the co-design workshop, which took approximately 35 minutes, participants were asked to complete the last two segments of the mapping card, focusing on visual expression and visual variables. Specifically, participants were prompted to consider how the tracking derived in the previous step could be visually expressed and to which visual variable the parameter could be mapped. To support creative thinking, R1 introduced examples from the Dear Data project (Lupi & Posavec, 2016), highlighting its use of unexpected and unconventional mappings between personal data and hand-drawn visual forms (Figure 4b). As Dear Data demonstrated the potential of non-obvious, personally meaningful mappings in personal visualization, and subsequent work has explored user-defined and expressive forms of personal data representation (Ayobi et al., 2018; Kim et al., 2019; Lan et al., 2024). We used Dear Data as a design reference to encourage participants to translate their tracking topics into creative visual languages. During this phase, R2 produced real-time rough sketches that reflected participants' proposed ideas and previously identified artistic preferences, allowing abstract mapping ideas to be externalized and examined immediately. In parallel, R3 assessed how the proposed visual variables and sketch elements could be technically implemented within the Datarium Frame system, guiding necessary adjustments to ensure feasibility.

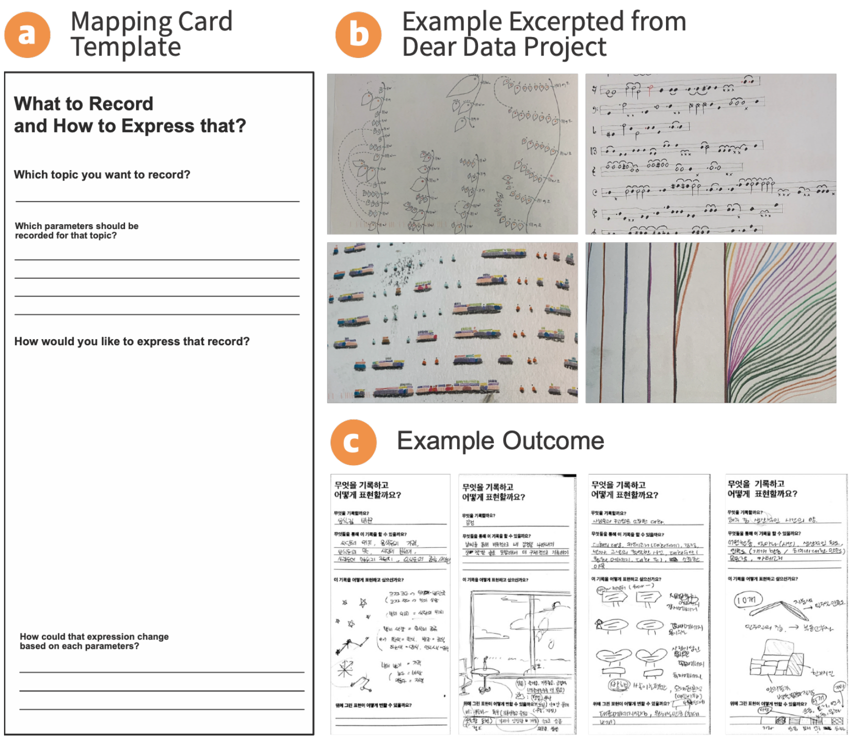

Figure 4. Material for co-design workshop to link tracking with visual expression.

Phase 3. Finalize initial personal sketch of visual representation: In the final phase, the mapping cards were integrated into the initial visual representation with the help of R2 (an artist). R2 drew two or three rough sketches of illustration concepts with different themes and compositions based on the mapping cards and selected the final digital illustration after discussing it with participants. During this process, some visual expressions that did not fit with the selected theme were modified, refining and implementing Datarium. Finally, R3 conducted a final feasibility review to ensure that the selected illustration could be dynamically linked to tracked data and implemented within the Datarium Frame system.

Refining and Implementing Datarium

Following the co-design workshop, the implementation of the six Datarium began for 4 weeks. This process involved 1) refining and developing final personal digital illustrations and 2) implementing the Datarium Mobile App and Datarium Frame's hardware and software.

Refining personal visual representation: Over 4 weeks, the visual representation (Table 1) was refined and developed. In the first 2 weeks, preliminary sketches were created based on participants' color and texture preferences. A feedback session on day 22 (Figure 2) gathered opinions on aspects like shape, size, pose, and alignment with the intended tone and manner. This informed future refinements. Using Adobe Illustrator, the semi-final version was developed, followed by a second feedback session on day 29 (Figure 2), involving the semi-final and final versions of the visual representation (Figure 5a) and mobile app (Figure 5b). Final digital illustrations were created using the P5.js library.

Technical implementation-mobile app and frame software: Datarium is a progressive web app (PWA) built with Next.js, compatible with iOS, Android, and the Datarium Frame. It uses MySQL as the database and redirects users to device-specific pages: the mobile app page for phones and a digital illustration page for the Datarium Frame. Illustrations, rendered with P5.js, update dynamically every 3 minutes by checking the database for changes.

Table 1. P2's Tracking and parameters of corresponding visual expression, visual variables, and visual representation concepts.

Tracking Topic	Tracking Parameter	Visual Expression	Visual Variable	Initial Sketch of Visual Representation
Workplace atmosphere	Greeting score Voice score Laugh score Customer score Call score	Rainbow	Sharpness of red color Sharpness of red color Sharpness of yellow color Sharpness of green color Sharpness of Blue color	
Listening to and singing music	Listening Place Genre Music Evaluation (If singed in Karaoke) Score	Book in Bookcase	Height of book position Book cover color Book size Book label color	
Countered number 4 [1]	Its meaning is positive or negative?	Lamplight	Brightness of light	
Coffee intake today	Coffee Type Aroma and Flavor Number of people drinking with	Coffee in cup	Coffee type Cup decoration Number of coffee cups piled up	

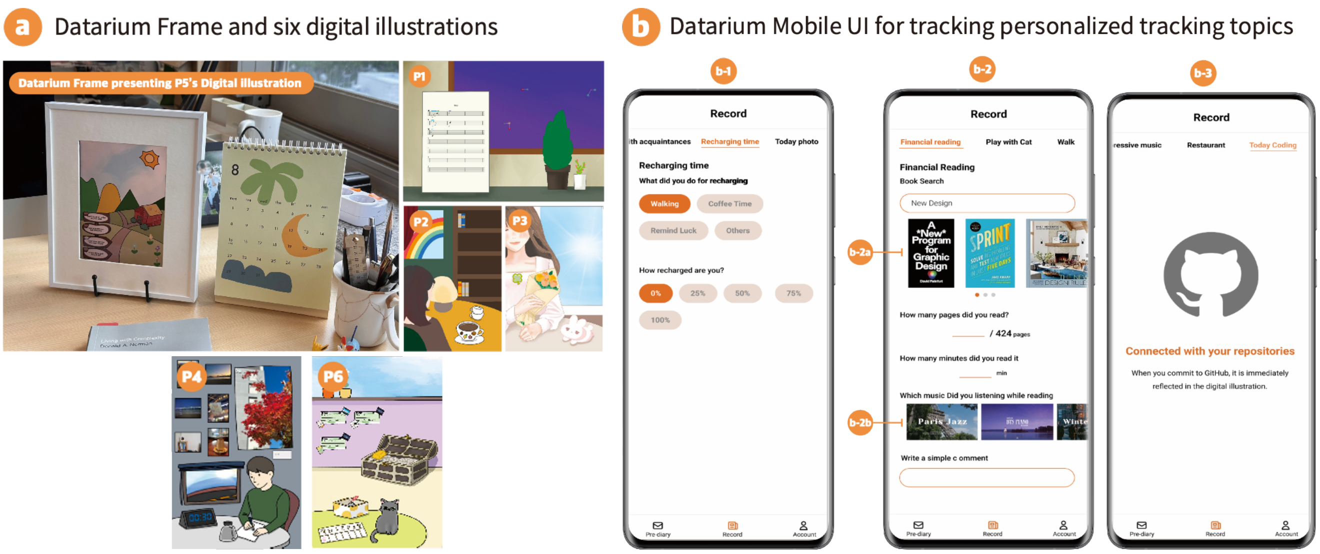

Figure 5. Participants' digital illustrations and Mobile UI for self-tracking.

Method2: *Field Study*

Deployment and Interview

We visited a participant's residence or office, deployed the Datarium Frame (Figure 6), and installed the Datarium App on participants' mobile phones. Three participants (P1, P2, and P5) installed the Datarium Frame at a non-private office, and three (P3, P4, and P6) installed it at their residences where they live alone. After installation, we demonstrated, using the user manual, how records from the mobile app are reflected in the visual representation in the Datarium Frame. Two interviews (at 7 and 14 days after the start of the field trials) were conducted. Two semi-structured interviews were conducted on days 7 and 14 after the deployment of the Datarium Frame. The first interview focused on participants' initial experiences of integrating Datarium into their daily environments, while the second interview addressed accumulated recording practices, reflective experiences, perceived privacy, and overall evaluations of Datarium (Table 2).

Data Collection and Analysis

Through the overall research process, we could derive the following: (1) 22 personalized tracking topics, including tracking parameters and corresponding visual variables [Table 1; see also Appendix 1]; (2) six visual representations in the form of digital illustrations for each participant [Figure 7; see also Appendix 2]; and (3) interview data containing experience of Datarium.

Personalized tracking topic and corresponding visual expression: We analyzed how participants mapped tracking data and parameters onto visual elements in digital illustrations, aiming to understand these patterns and use them to interpret field study findings. Using open and axial coding, affinity diagramming, and iterative grouping, three researchers independently categorized tracking—visual expression to reduce potential bias. This process identified seven non-mutually exclusive categories, as detailed in Table 3.

Figure 6. Datarium Frames deployed in offices (P1, P2, and P5) **and residence** (P3, P4, and P6)**.**

Table 2. Interview topics by weeks.

Day	Main Interview Contents
First Interview (Day 7)	• Initial experiences of using Datarium in everyday environments • Placement of the Datarium Frame and its accessibility in daily routines • Early encounters with changes in visual elements reflecting recorded data • Initial motivation to record triggered by Datarium's visual representations
Second Interview (Day 14)	• Ongoing recording behaviors supported by Datarium's visual changes • Experiences of casual reflection through glancing at the Datarium Frame • Interpretation of personal data through user-defined visual encodings • Perceived privacy when displaying Datarium in shared or private spaces • Overall evaluation of Datarium and feedback on design improvements

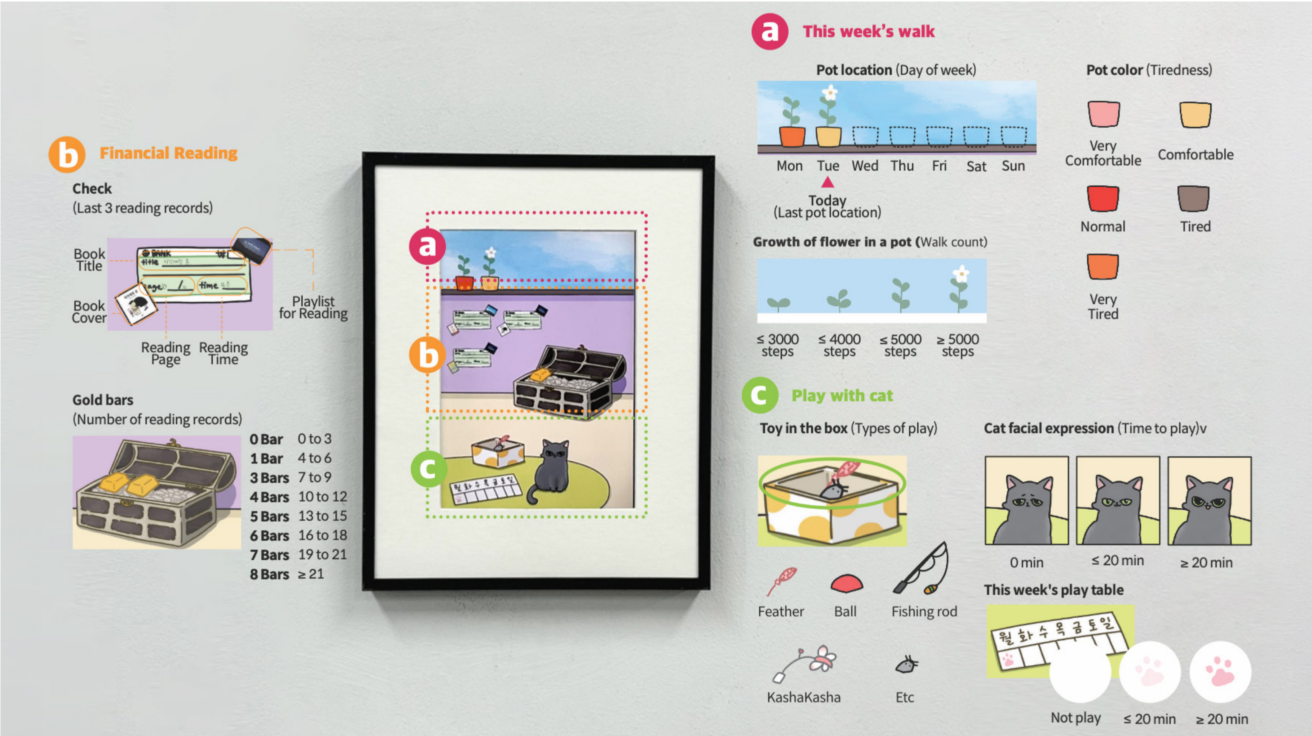

Figure 7. P6's visual representation and change of visual variables based on tracking parameters.

Table 3. Seven patterns for mapping tracking to visual expressions.

Patterns (Frequency of occurrence)	Description
1. Preferred Entity (9)	Participants used meaningful or cherished objects to represent their recorded information, as shown in Figure 8.a. For example, P4 chose an ink bottle and fountain pen to symbolize rest or recharge time, with the pen holding sentimental value as a gift from a close friend. Similarly, P3 incorporated a rabbit doll, reflecting her fondness for rabbits, to represent exercise tracker data, while P6 used her cat's facial expression as an avatar to illustrate time spent playing with her pet (Figure 8.a, right).
2. Personally defined semantic relation (7)	It is a pattern that involves using an individual's personal idea or meaning of an object, formed through their experience or knowledge acquired from episodic memory, to map the information being conveyed onto that object. For example, P1's coding tracker was based on the growth rate of plants in pots (Figure 8.b, left), as they perceived the heat map, which indicates the coding activity level on GitHub, to resemble grass. In another instance, P2 depicted the work atmosphere with the clarity of a rainbow (Figure 8.b, right), as they were reminded of one in the sky upon leaving a job interview.
3. Conventional Semantic Relation (10)	This pattern is very similar with the semantic associations mentioned in Nakamura and Zeng-Treitler (2012) research, which is not explicitly depicted and requires inferential power to obtain the information from the representation but is still interpretable if they belong to the same culture and social group. P1's musical score that presents a record of music and P3's sweat towel of a rabbit doll illustrates the exercise tracker (Figure 8.c, right) involved in this pattern.
4. Iconic Relation (2)	This pattern is similar to an iconic relationship, categorized by Bühler et al. (2022). More specifically, an iconic relation occurs when the shape is taken and used as is. For example, P2's coffee record expressed different types of coffee (i.e., espresso, americano, and lungo) with coffee in a cup (Figure 8.g), and P6's playing with cats used objects, such as balls and fishing rods.
5. Direct Representation (4)	This pattern also draws from the research on iconic relation by Bühler et al. (2022). However, unlike signs used in iconic communication, Datarium's visual representation includes not only objects but also photos and text. In this context, direct representation refers to the method that presents records, such as a text string or a photo, as visual representations without any abstraction. For example, P4's photo and comment (Figure 8.d, right) and P5's cherished message (Figure 8.d, left) involved this pattern.
6. Binding with other Elements (4)	This refers to the method participants use to show a relationship between two unrelated types of tracking. For example, P1 represented the music he heard while performing the task as musical notes below the musical score, indicating today's schedule (Figure 8.e, top). Similarly, P6 presents a check, a financial book reading tracker with a YouTube music thumbnail sticker, which refers to music listening while reading (Figure 8.e, bottom).
7. Matching with Art Theme (4)	To integrate harmoniously with the overall theme of the digital illustration (visual representation), which comprises diverse visual expressions, certain visual presentations were modified from their initial conceptual versions. For example, P5 chose flowers and mountain ranges as visual expressions suitable for drawing, such as houses and signposts. For P1, the initial coding tracker was encoded as a forest but adjusted with flowerpots to integrate with constellations outside the window and the score on the piano.

Interview data analysis: All interview contents were transcribed and analyzed using thematic analysis (Braun & Clarke, 2012). To ensure triangulation in the data analysis, three researchers independently conducted open coding, followed by axial coding, on the user experience of Datarium. Each researcher independently derived initial open codes by identifying meaningful, frequently mentioned user quotations. Following this, the team compared the generated codes and reached consensus on those commonly identified or mutually validated, resulting in a total of nine core codes (Table 4). To further ensure an unbiased review and reflect objective perspectives, we recruited two additional researchers who were not involved in the collaborative design or field study phases. During the consensus-building process, these external researchers provided new insights and helped resolve any disagreements through collaborative discussion. Finally, we iteratively grouped these nine main codes to derive the themes and final findings (Figure 9).

Figure 8. Example of visual expressions associated with each category.

Table 4. The key codes derived from author' triangulation.

Main Code	Grouped by	Mentioned by
Intriguing Visualization	A1, A2, A3	All Participants
Motivate to Record	A1, A2, A3	P1, 2, 4, 5, 6
Want to change visual state of art component	A1, A2, A3	P1, 2, 4, 5, 6
Unconscious glancing	A1, A2, A3	P1, 2, 3, 4
Capture the info at a glance	A1, A2, A3	All Participants
Attachment toward element derived from co-design	A1, A2, A3	All Participants
Reluctance to present personal record to others	A2, A3	P1, 2, 4, 5
Prevent record from lapsing	A1, A2	P1, 3, 5, 6
Visualization for casual daily review	A1, A3	P1, 2, 5, 6

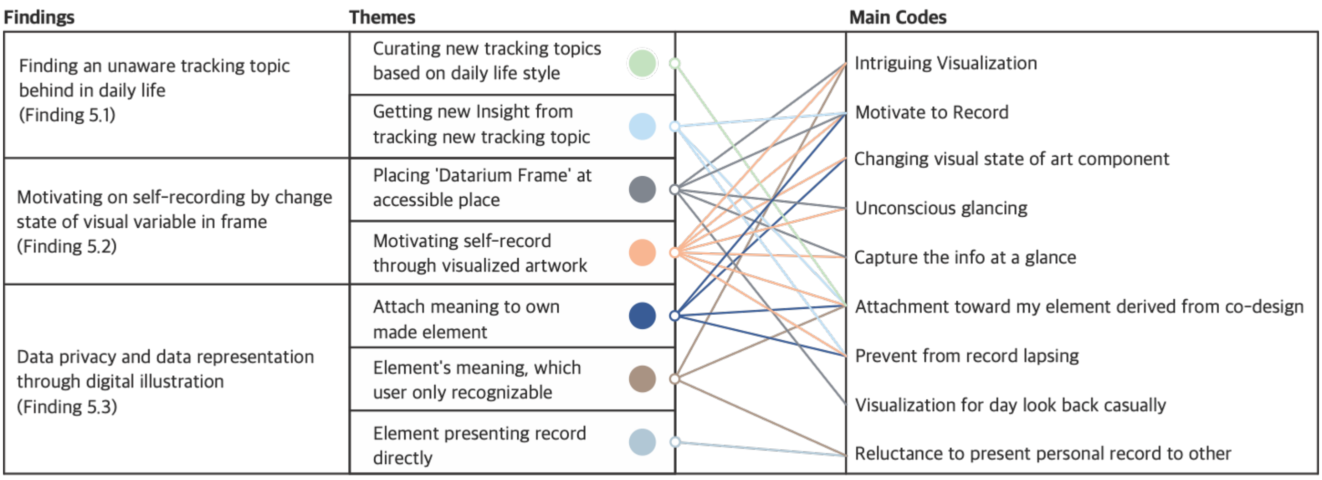

Figure 9. Comprehensive process of qualitative data analysis.

Findings

Surfacing Unrecognized Tracking Opportunities

All participants acknowledged that recording their experiences with tracking topics, derived from a collaborative design and implementation process, could raise awareness of their previously overlooked tracking needs. Regarding this, P1 noted, "I thought that I could record something like this! Especially it was memorable since it is my first time to record about restaurant."

These overlooked tracking topics could be identified by reflecting on their lifestyles or past experiences facilitated by reflective questions provided during the co-design workshop. Even if it required by the researchers' involvement rather than being a direct outcome of the Datarium system itself (Phase 1 of the co-design workshop), our study process illustrated how a structured approach could surface opportunities for these unaware tracking topics. The responses to the pre-diary questions about daily life and experiences served as anchors, sensitizing participants to their lifestyles. These responses were then used in the co-design workshop to facilitate reflective questioning, which helped participants look deeper into their daily routines. This approach allowed participants to connect their routine behaviors to their internal motivations, uncovering meaningful topics they had previously unrecognized. For example, through responses from the pre-diary, we identified that P2 considers the workplace and relationships with colleagues important. We then asked P2 questions like, "Why is your workplace important to your life?" and "What makes you happy in your workplace?" The conversation that ensued led P2 to mention the joy she derived from the positive atmosphere created by colleagues, and she suggested recording aspects such as office laughter and customer satisfaction as meaningful tracking topics. Integrating this, P2 ultimately developed an "Atmosphere of Workplace Tracker," a concept she had not previously considered recording. Moreover, all participants mentioned that conversations with the researcher were instrumental in discovering new tracking topics. Regarding this, P5, who came up with 'Call with parent' and 'Change of mood' mentioned that "It is interesting to think what could be recorded. Rather than just thinking about what to record by myself, I think things that I hadn't thought of came to mind while talking with the researchers."

This finding is in line with Rapp and Cena (2016), suggesting that although people may not consciously recognize them, there are latent tracking needs in their daily lives. In addition, we also found that even for people who keep records, it is difficult to decide [mentioned in (Epstein et al., 2015)] a new tracking topic that they had not previously done. To develop a new but potentially meaningful tracking topic, the careful process of observing their lives is needed.

Moreover, we could confirm that recording-unaware tracking topics help participants gain new insight into themselves. Concerning this, P6 stressed that

> (in the workshop) I thought it would be good to record the time I played with my cat (Play with cat). And when I tried it myself, I realized it was a necessary record for my daily life. I also played with my cat more. (P6)

Similarly, P5 mentioned,

> I feel like I learned something about myself that I didn't know before. I recorded my mood for the day (before the study) but didn't think I would change my mood within a day. As I recorded this, I was surprised that my mood changed faster than I thought and lasted for a shorter period. (P5)

This finding reflects previous studies (Karyda et al., 2020; Kim et al., 2019) that provide triggers closely related to users' personal context for recognized tracking topics, such as questions or cherished objects (Tsai & Hoven, 2018). Moreover, we also identified that enhancing awareness of participants' daily life experiences can help derive new tracking topics based on that awareness However, it remains unclear how users can independently encounter these triggers and derive topics without external mediation. This highlights a potential area for discussion regarding how such reflective guidance can be systematically embedded into self-tracking tools to support the capture of unaware tracking opportunities.

Motivating Recording through Visual State Changes

Our study revealed that using the Datarium Frame to display personal records can serve as a motivational tool. This finding suggests that the Datarium Frame can enhance motivation through two mechanisms: 1) It increases accessibility to one's records, and 2) It enables changes to the elements in the visual representation of digital illustrations based on the content of the records.

Increased Visibility and At-A-Glance Access

All participants reported that the digital illustration caught their attention without conscious effort, particularly during moments of distraction from work (e.g., sitting down or standing up, spacing out, or stretching while working at their desk). For instance, P4 said,

> I do not see the past diary after writing a diary, but this one [Datarium Frame] always shows it updated on the designated spot, so I think it is good [in terms of reminding]. There is a moment when I space out or move my head slightly when I type at a computer, which induces me to notice the frame. Every time I encounter a frame, I think there is something that helps me remember [about the record]. (P4)

Furthermore, the integration of records from various tracking topics into a single digital illustration in Datarium allowed users to conveniently monitor their areas of interest without further manipulation. P3 and P6 expressed their satisfaction with Datarium's ability to provide a brief overview of their goals and daily life records at a glance, eliminating the need to switch between apps or select individual tracking records. Similarly, P4 expressed,

> The design of the Datarium Frame is effective in combining the three elements into one, making it easy to grasp at a glance. Additionally, the convenience of not having to touch or swipe to operate it allows for easy and brief viewing. Even without any explanation, I perceive a connection between the picture, the numbers, and the colors, unifying the record and the visual representation. (P4)

In line with previous research (Gouveia et al., 2016; Matthews, 2006), it has been shown that the use of ambient displays enables the swift, subconscious checking of information at a glance. Furthermore, Datarium has incorporated visual expression, seamlessly integrating a digital illustrator into a frame. This integration imparts an enhanced sense of overall visual coherence and interest.

Encouraging Recording via Visual Changes

All participants in the study reported that completing the visual expression of Datarium's digital illustration, such as filling in the bookshelf or changing the cat's facial expression, gave them a sense of satisfaction and completion, and they found it interesting to fill in or gradually change the picture through this process. P2 commented on this experience, stating, "I feel a sense of pride every time I see the books on the bookshelf stacking up over the course of a week. It's like decorating the interior [of a room in the picture]."

Furthermore, through interviews with four participants, we found that both the enjoyment of recording and expressing and the potential for continuous recording over the 2-week study period may have induced a novelty effect. Regarding this, P3 expressed,

> If the artwork's [digital illustration] state is stopped in the old record, I reflect on myself, saying, 'I didn't record it.' In the case of a bouquet, I sometimes think, 'I have something to do today, so let's fill my record to complete [bloom] the flower in the bouquet. (P3)

Similarly, P6 stated,

> The change in the cat's facial expression in the artwork feels a bit like my Mimini [the name of her cat], like an avatar... It seems more touching because it is a picture. It resembles my cat, and when it looks sullen, [it makes me think] that I should play [with my cat]. P6)

The aggregation of participants' comments confirms that recording and visualizing records through Datarium is engaging, as it motivates users to complete a picture by highlighting what is not yet recorded or unfinished. This aligns with prior research on alternative data representation, in which Thudt et al. (2018) suggested that users' motivation for recording can be sustained by the desire to achieve aesthetic completion or an ideal state in their physical construction. Similarly, Park et al. (2025) noted that curiosity about what kind of image will be generated from their input is a significant source of motivation for consistent tracking. In a similar vein, our findings confirm that the desire to change an unwanted visual expression in a digital illustration—such as transforming a "sullen" cat into a happy one—can prompt individuals to record and act, effectively leveraging the visual state as a feedback loop for self-improvement.

Perceived Privacy through User-Encoded Visual Representations

Through field studies, we confirmed that encoding personal data into visual expressions by users can provide a perceived privacy affordance, mitigating the risk of others from inferring the meaning of the visual expression depending on the method of mapping the tracking—visual expression (Table 3). Participants stated that the encoding method of the data—visual expression is typically understandable only to them, unless it has a direct (i.e., the fifth pattern in Table 3) or highly conventional semantic meaning (see the 5th and 3rd pattern in Table 3, respectively). For instance, P4 stated,

> I think I was able to easily recognize the meaning because I decided on the meaning [of each picture's element]. It would be difficult [to recognize] if someone else made it. I think people can know [the meaning of] things like time [representation in clock, which is involved in iconic relation] and photos representing directly [direct representation in Table 3], but only I can figure out the ink bottle [preferred entity] being filled and other things. In my thought, if those [visual elements only I can recognize] were made by someone else, I guess it would have not touched me like this. There was a side that was easier to recognize because I had something decided. (P4)

P6, who installed Datarium in the privacy of her apartment, suggested that it would be acceptable to install it in the workplace if there were no elements directly expressing information among the existing records. She mentioned that,

> If I installed it [Datarium] at work, I don't think it would record my financial readings. But I think it would have been fine if it was expressed only with gold bars (conventional semantic relation). The title and cover of the book are direct [so, it is to know] ... I guess people will only think of 'what is it?' with gold bars. Also, it would be difficult to think of the number of steps that a flower pot grows [matching with art theme]. (P6)

By integrating participants' mentions and tracking visual expression-matching patterns, we see that direct encoding of personal data into visual expressions may limit others' interpretability of data elements, making them less accessible unless they are involved in direct representation, iconic relation, or highly conventional semantic relation.

Three participants (P1, P2, and P5) installed Datarium in offices where the digital illustration was visible to others. This environment is characterized using personal desks within relatively intimate social relationships, yet it inherently carries the risk of social surveillance and unintended data exposure. However, they felt it was difficult for others to interpret the recorded data, except for P5, whose record was more direct. P5 was cautious, only recording messages acceptable for public viewing. Additionally, P5 believed topics such as phone calls with parents and family memories were difficult to infer because of their uncommon nature. The use of shared visual variables further obscured the meaning, making interpretation by others challenging. Regarding this, she stated,

> Of my art, I don't think people will be able to guess [what they mean] about the flowers and the sun. First of all, it is not common to record talking with my parents. Also, there are many things that can be expressed because it is expressed as something that is or is not. And in the case of flowers, they seem not to be directly related to family memories, so it will be difficult to connect them. (P5)

Similarly, P2 expressed that a single visual expression could be interpreted in multiple ways, and by using this approach, the meaning of the secret record could be disguised. She stated,

> It's a secret that only I can understand, so even if there is a record like this, it doesn't matter if I put a frame in the office because only I know the meaning. Also [because it is expressed indirectly as an element of a picture], it could have a sufficiently different meaning. If someone asks the meaning of the record, I think I can say it in other popular meanings. (P2)

Thus, the participants' perception was that encoding personal data into visual expressions through Datarium could provide a level of privacy and prevent easy inference by others, especially when the tracking was not commonly understood or was expressed indirectly.

Kim et al. (2021) noted that individuals may hesitate to share personal information, even if not sensitive, in everyday environments. However, the Datarium Frame's data expression method provides a sense of security, as it is not easily interpretable by others. Similar to Karyda et al. (2020) approach of mapping personal data to entities (e.g., objects, visual expressions) based on lived experiences, this method produces unexpected matches, making interpretation difficult for others. Snyder et al. (2015) described this as a 'private key,' enabling only the individual who encoded the data to understand its meaning. This reduces the burden of displaying personal information in public or shared spaces. Our study confirmed that applying this approach to visual representations enables self-encoding to serve as a private key, since a single visual expression can carry multiple interpretations, thereby enhancing the perceived security of personal information.

Discussion and Design Implication

Based on our overall research findings from both the collaborative design process and field study, we derived several design implications for designing self-tracking systems that effectively represent personalized topics.

Supporting the Elicitation of Unrecognized Tracking Opportunities from Everyday Life

To derive tracking content that provides meaningful personal insights, it is essential to consider users' everyday lifestyles and lived contexts. Prior self-tracking systems, such as OmniTracker (Kim et al., 2017) and Trackly (Ayobi et al., 2020), enable users to flexibly define custom trackers by selecting topics, parameters, and schemas. However, prior work has also shown that users often struggle to articulate what is meaningful to track in the first place (Li et al., 2010), leaving many potential tracking opportunities unrecognized.

In our study, such unrecognized tracking opportunities did not emerge directly from the Datarium system itself, but rather through a facilitated elicitation process embedded in the collaborative design workshops. Life-relevant and reflective questions prompted participants to revisit aspects of their daily routines, environments, and experiences that were previously overlooked or taken for granted. Through this process, participants were able to reinterpret mundane or habitual activities as personally meaningful and potentially trackable. Building on this first finding, we discuss how the reflective questioning structure observed in our workshops—rather than the workshop format per se—can be abstracted and operationalized within future self-tracking systems. Rather than prescribing what users should track, such systems can be designed to support reflective sense-making by framing everyday experiences in ways that help users surface their own tracking opportunities.

One possible design direction is to support this elicitation process through a gradual, two-step structure. The first step focuses on sensitizing users to their personal contexts by collecting lightweight, open-ended reflections—such as meaningful objects, recent experiences, or daily anecdotes—as demonstrated in our pre-diary study and prior work (Kim et al., 2019). These reflections can serve as contextual "seeds" that attune users to patterns in their own lives. Computational techniques, including large language models (LLMs), may be leveraged at this stage not to determine tracking topics but to help organize and highlight salient themes or recurring elements in users' own narratives (Lim et al., 2024). Unlike generic tracking suggestions (e.g., steps or mood), this approach foregrounds users' lived experiences as the primary source of meaning.

The second step involves presenting reflective prompts derived from these contextual seeds in ways that preserve user agency and autonomy (Shneiderman, 2022). Rather than explicitly recommending what to track, the system can surface prompts that invite users to reinterpret their recent experiences—for example, by asking them to notice meaningful items in their surroundings (Bressa et al., 2022) or reflect on personally cherished objects (Karyda et al., 2020). Importantly, users remain free to ignore, reinterpret, or act upon these prompts, ensuring that tracking topics emerge through personal reflection rather than system prescription.

Context-awareness can further support this elicitation process by aligning reflective prompts with moments when users are more receptive. Spatial, temporal, or situational cues—such as recent locations, calendar events, or periods of rest—may help identify appropriate moments for reflection without imposing interruptions. In this way, contextual sensing supports when reflection is invited, rather than what should be recorded.

Overall, our findings suggest that identifying meaningful tracking content benefits from a slow, reflective process of questioning rather than from immediately defining tracking variables and initiating data collection. By embedding facilitated elicitation mechanisms into self-tracking systems, designers can help users recognize previously unacknowledged tracking opportunities while preserving autonomy and respecting the exploratory nature of personal reflection.

Showing In-Depth Information in Digital Illustration Representation

Our field study found that always-on digital illustrations prompted unconscious checking behavior (Kim et al., 2022; Mols et al., 2020) as users naturally glanced at the frame in daily life.

Visual cues, such as unbloomed flowers or empty bookshelves, encouraged reflection and action. However, the Datarium method is limited to momentary snapshots and lacks detailed insights into tracked records. These findings suggest enhancing visualizations to provide deeper information, uncover relationships, and foster user engagement.

Careful consideration is required when presenting different tracking methods by integrating them into a visualized digital illustration to facilitate users' data sensemaking of the entangled relationships among records. Rapp and Cena (2016) confirmed that self-trackers want information about their interests at a glance. However, in Datarium's digital illustration, records of different tracking topics are visualized independently, which does not effectively convey their relationships. A few records, including those linked to another tracking topic, were presented and helped users think about their relationships [such as P1's music listening and to-do list through a musical score, and P6's financial reading and listening to music through a check (Figure 8e)]. Furthermore, some participants perceived a connection between the presented records because they were integrated into the same digital illustration. This suggests that while it may be challenging to depict statistical elements, such as variance and a correlation coefficient, through visual expression in digital illustrations, it is possible to facilitate participants' sensemaking of data by identifying expressive and exploratory stories conveyed through Datarium's digital illustration, rather than solely seeking objective truth from data (Weick et al., 2005).

Snyder et al. (2019) employed an approach that involved deriving a sensemaking challenge for bipolar disorders from visual images, which was then used for visualization. This approach can be applied to facilitate users' interpretation of visual elements in the digital illustration through their interactions with one another. For example, influencing factors (e.g., the number of snow particles; see Figure 10a-1) and affected factors (e.g., snow accumulation on the tree; see Figure 10a-2) can be included in the digital illustration. If the number of snow particles changes depending on the user's mood record and the amount of piled snow on the tree changes (Figure 10a-b) based on sleep time, users can make their own interpretation of the story in the digital illustration by relating their sleep time and current mood, thus facilitating their data sensemaking process.

Perceived Privacy Affordance through User-Only Recognizable Visual Representations

In the representation of personal data, a delicate balance is required between disclosure for self-reflection and the risk of unintended exposure (Snyder et al., 2015). Displaying data in everyday environments can foster serendipitous encounters with one's data, leading to opportunities for self-reflection and personal growth (Kim et al., 2022; Thudt et al., 2018). In particular, ambient data representations can act as social triggers that spark curiosity and facilitate conversations with others (Park et al., 2025; Snyder et al., 2015; Thudt et al., 2018). However, this social visibility functions as a double-edged sword; while it promotes engagement, it also imposes the burden of unintended exposure and a heightened sense of social accountability (Snyder et al., 2015; Xu et al., 2025)

We found that maintaining a balance between disclosure and privacy is essential in shared workspaces where colleagues' gaze is constant. Although such environments are prone to unintended disclosure (Kim et al., 2021; Schaub et al., 2014) The use of abstract visual representations offers a privacy affordance, allowing users to display personal data with greater privacy, even under social scrutiny. This affordance becomes especially important in mitigating the risks posed by "direct representation" (the 5th pattern in Table 3), where text or photos are presented without an inference process, making data vulnerable. To address these concerns and the inherent tensions of shared workspaces, we propose several design implications to ensure perceived privacy when encoding record data into visual expressions.

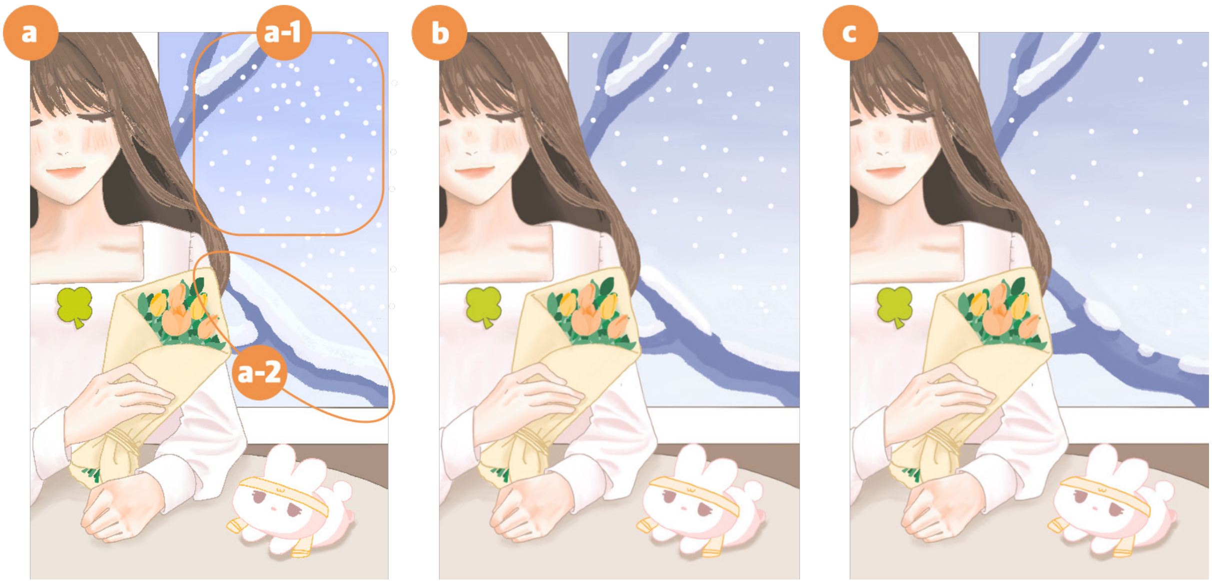

Figure 10. The concept enhances data sensemaking by linking snow particle counts to tree-branch snow levels.

Use One-To-Many Relationships between Visual Expression and Its Meaning For Perceived Privacy

The way information is presented can serve as a "key" to connect data and expression. For instance, Moodlight (Snyder et al., 2015) uses the color of the light to map users' internal state, and it emphasizes that providing a customization option to select the color—internal-state pair could serve as a private key for interpreting information from the lamp. At this point, Datarium's data presentation method is determined by the user, enhancing their perceived privacy and helping them feel more psychologically secure. This arises from the fact that one visual expression could contain multiple meanings, as described by Cowgill et al. (2003). Our field study has demonstrated that participants feel safe about data privacy with the Datarium Frame because it represents their records using visually indeterminate elements. The perceived privacy is further reinforced when the visual expressions are encoded with personally defined semantic meanings (the 2nd pattern in Table 3), such as rainbow—workplace or book—music, which are difficult for most people to infer. Additionally, some participants feel secure with socio-culturally interpretable semantic meanings (the 4th pattern in Table 3), such as financial—check or luck—clover, even if the visual expression may have alternative meanings that are difficult to specify.

Alternate Data Representation for Direct Data Representation

When exposing personal data in everyday spaces through ambient displays, "direct representation" (the 5th pattern in Table 3)—which presents photos or text strings directly without visual encoding—can provide information to others without requiring any inference process. To address this concern, Park et al. (2025) utilized prompts that strictly prohibit the direct depiction of data when transforming user records into AI-generated images. This approach enabled safe self-disclosure by creating ambiguous visualizations. Similarly, for systems like Datarium, where users manually map data to visual expressions, alternative means are necessary to mitigate the privacy vulnerabilities of direct representation and ensure a perceived privacy affordance.

Various strategies could be applied to the Datarium Frame to enhance perceived privacy through alternative representations of photos or text. The simplest way is to provide a hide mode that presents data directly in an alternative form before the user's authentication, such as a password or face recognition. Another way is to change data in an alternative way based on the position frame (Kim et al., 2021) of the Datarium Frame or utilizing context-adaptive privacy (Schaub et al., 2014), which recognizes people within a certain space and adjusts the representation accordingly. Regarding alternative representations of photos, the blur effect or lowering the image resolution (Pierce & Paulos, 2014) could be applied in an abstract way to present user images. In the case of text, user records could be updated to popular phrases or news excerpts.

Limitation and Future Work

Despite these insights, our study has several limitations. During the co-design workshop, topic selection may have been influenced by researcher-led questions, and visual expressions may have been shaped by earlier examples. While the small sample size allowed for in-depth observations of unique personal contexts, it is difficult to generalize the specific tracking topics or visual preferences identified in this study to universal user characteristics. Additionally, the lack of a dedicated phase to finalize the theme necessitated adjustments when integrating visual elements into a cohesive illustration. In the Datarium field trial, the short 2-week duration may have been subject to a strong novelty effect, limiting our understanding of the system's long-term effectiveness. While participants initially felt secure, it remains to be seen whether others could eventually infer the data's meaning over time. Future research should examine how users respond when the meaning of their data is leaked and how these privacy dynamics shift depending on their relationships with others. Furthermore, participants might alter their encoding methods or the topics they track as their privacy concerns evolve over time.

Conclusion

This paper introduces Datarium, a tracking system that allows users to record personalized data and visually represent their records as digital illustrations. We present a 5-week collaborative design process aimed at exploring which tracking could be extracted and encoded in visual expression through digital illustration. We also conducted a 2-week field trial with six participants to investigate how they perceived Datarium and which experiences it could deliver. The study revealed that participants were able to recognize their previously unacknowledged tracking needs by observing and reflecting on their daily lives and encoding their records into visual expressions using seven different strategies. Moreover, the field study found that a digital illustration motivated users to record by altering its visual variables. Through a collaborative design process and field study, our Datarium design offers potential insights for designing personalized self-tracking and metaphoric data visualizations.

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Endnote

1. Recording encounters with the number 4 in everyday life (e.g., noticing the time is 4:44 or seeing an elevator stop at the 4th floor)

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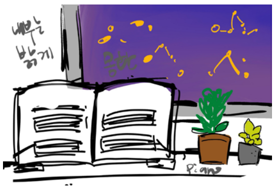
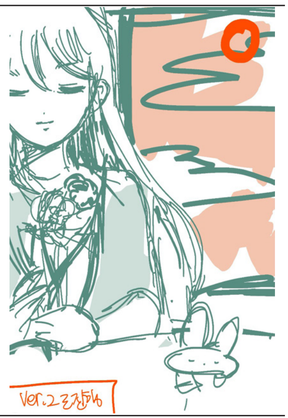
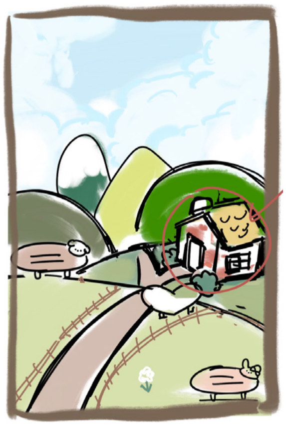
Appendix

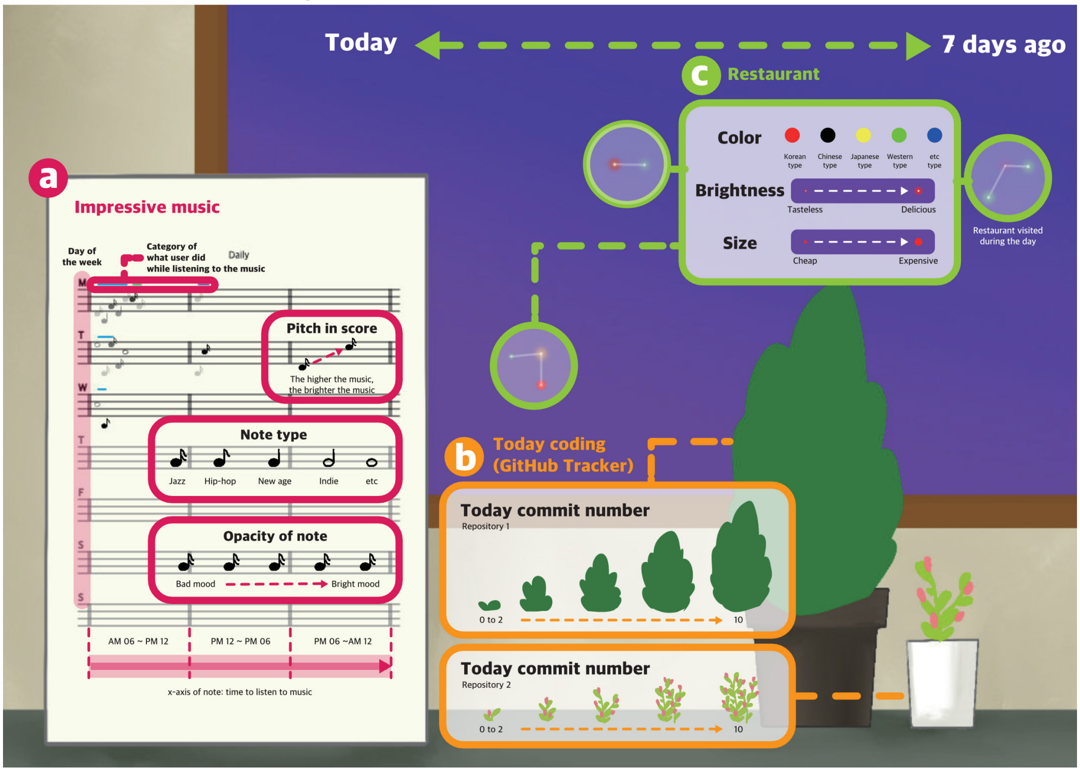
Appendix 1. All participants' tracking topics, tracking parameters of corresponding visual expression and visual variables, and derived artwork concept from a co-design workshop.

Code	Tracking Topic	Tracking Parameter	Visual Expression	Visual Variable	Initial Sketch of Visual Representation
P1	Impressive music	Genre	Musical note in score	Note type	
		Music's mood		Pitch in score	
		Emotion evoked from music		Opacity of note	
		To-do	Line cove on note	Line	
		Event category		Line's color	
		Start time and end time		Line length	
	Restaurant	Flavor score	Constellation	Star size	
		Price		Star brightness	
		Location		Direction of next star	
		Food type		Start color	
	Today coding (GitHub Tracker)	Repository belonging code	Plant in the pot	Plant type	
		Today commit number		Degree of growth	
P2	Workplace atmosphere	Greeting score	Rainbow	Sharpness of red color	
		Voice score		Sharpness of red color	
		Laugh score		Sharpness of yellow color	
		Customer score		Sharpness of green color	
		Call score		Sharpness of Blue color	
	Music listening and singing	Listening Place	Book in bookcase	Height of book position	
		Genre		Book cover color	
		Music Evaluation		Book's size	
		(if it singing in Karaoke) Score		Book label color	
	Encountered number 4	It's meaning is positive or negative?	Lamp's light	Brightness of light	
	Today coffee intake	Coffee type	Coffee in the cup	Coffee yype	
		Amora and flavor		Cup's decoration	
		Number of people drink with		The number of coffee cups piled up behind	
P3	Emotion	Type	Weather	Sunny, moderate, cloudy rainy and snowy	
		Scale (Sunny and rainy only)		Brightness and heaviness of rain	
	Luck	-	Clover necklace	Luck fill the clover necklace with green liquid gradually	
		Comment		-	
	Walk	Do/not	Rabbit doll	Rabbit's sweat towel	
	Achievements	To-Do	Bouquet	Number of bloomed flowers	
		Archived /not			

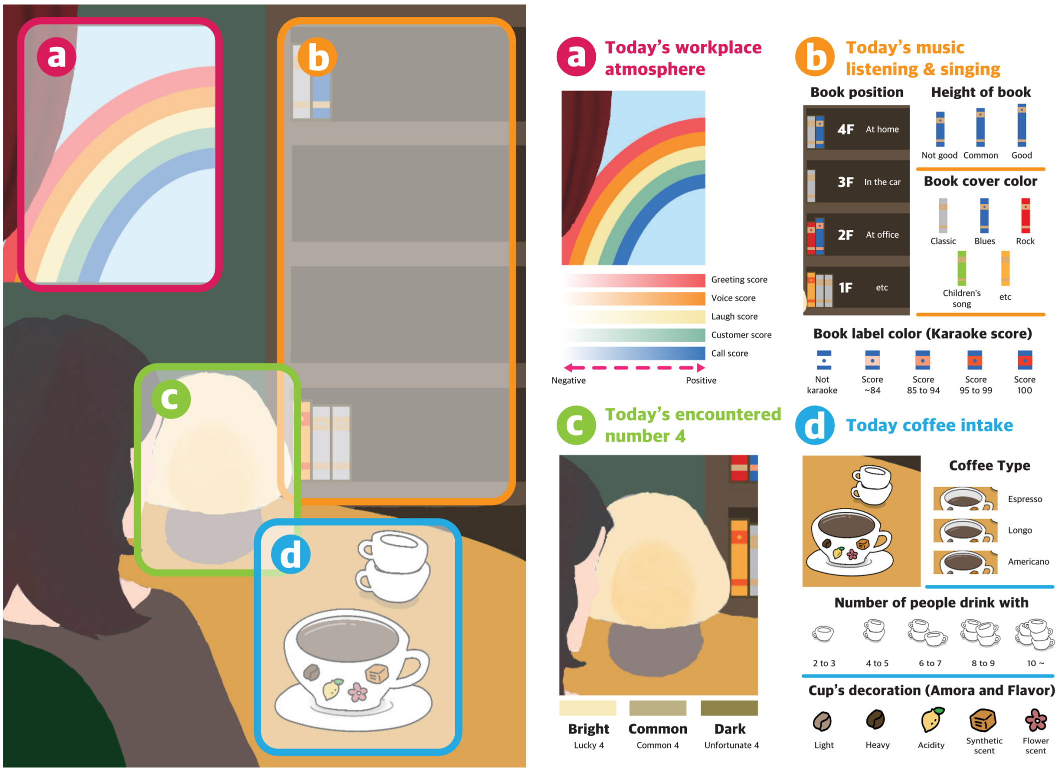
Appendix 1. All participants' Tracking topics, tracking parameters of corresponding visual expression and visual variables, and derived artwork concept from a co-design workshop (continued).

Code	Tracking Topic	Tracking Parameter	Visual Expression	Visual Variable	Initial Sketch of Visual Representation
P4	Time with acquaintances	Place	Landscape of window and clock	Landscape	
		Purpose		-	
		Spent time		Clock time	
		Conversation topic		Color of clock number	
	Recharging time	What I do for recharge	Ink bottle	Color of ink	
		Satisfaction		Filled amount	
	Today photo	Photo	Polaroid	Photo on polaroid (if not main photo)	
		Comment		Text on label (if main photo)	
		Main photo / not		Located at big frame	
		Taken place		-	
P5	Change of mood	Type	Ridge of mountain	Mountain shape	
		Strength		Mountain height	
		Duration of mood		Mountain width	
	Cherish message	Message	Sign	Message on sign	
		Type		Shape of sign	
		Sender		Character on sigh	
	Productive time	Activity	House on construction	Brick pattern	
		-		Roof is present when N brick was pilled	
	Memory with family	Photo	Flower	-	
		Number of family members in memory		Number of flower leaves	
		Type		Flower color	
	Call with parent	Do/not	Sun	Sun's present	
P6	Financial Reading	Book	Check and gold in safe	Use book cover as tape to fix check	
		Reading page		Text on check	
		Reading time		Text on check	
		Music playlist for reading		Use thumbnail cover as tape to fix check	
		Comment		Sharpness of blue color	
	Play with cat	Types of play	Cat and toy box	Toy in the box	
		Time to play		Cat facial expression and play table	
	Walk	Walk count	Flower in a pot	Growth of flower in a pot	
		Tiredness		Pot color	
		Comment		-	

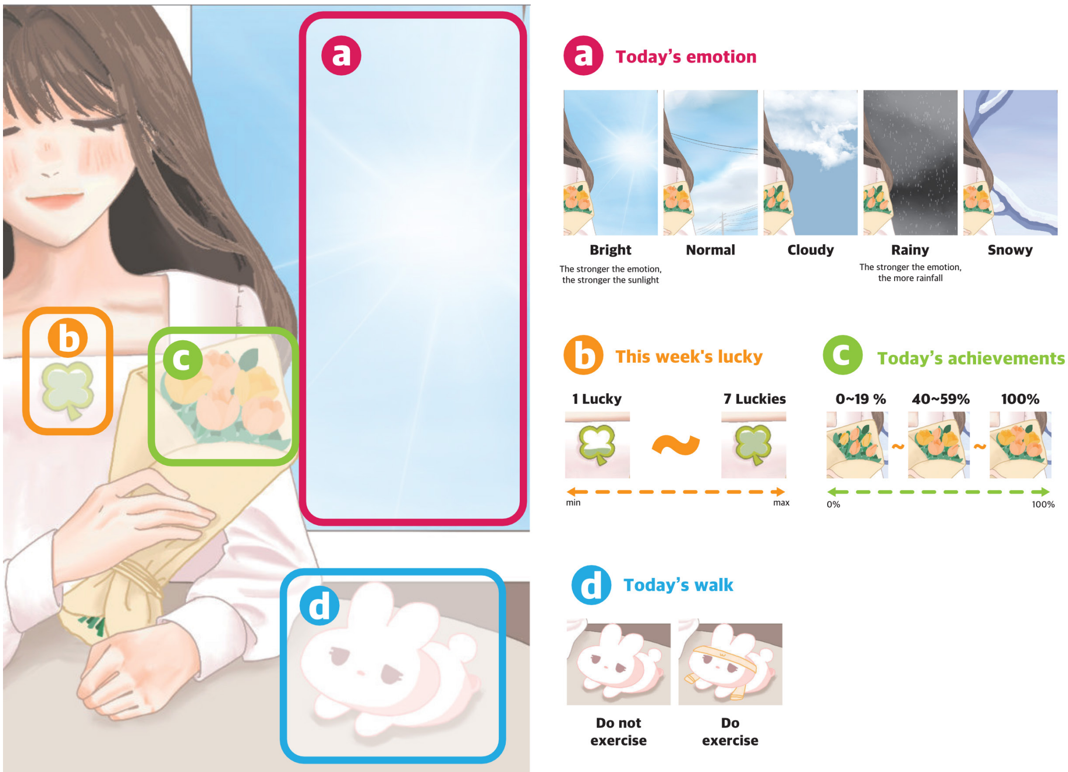
Appendix 2. Implemented participants' digital illustrations.



Appendix 2-1. P1 decided to record 1) impressive music, 2) a restaurant, and 3) today's coding through the Datarium above image to illustrate P1's digital illustration. Based on the impressive musical score, a constellation outside the window was presented for the visited restaurant, and plants were grown based on today's computer coding progress.

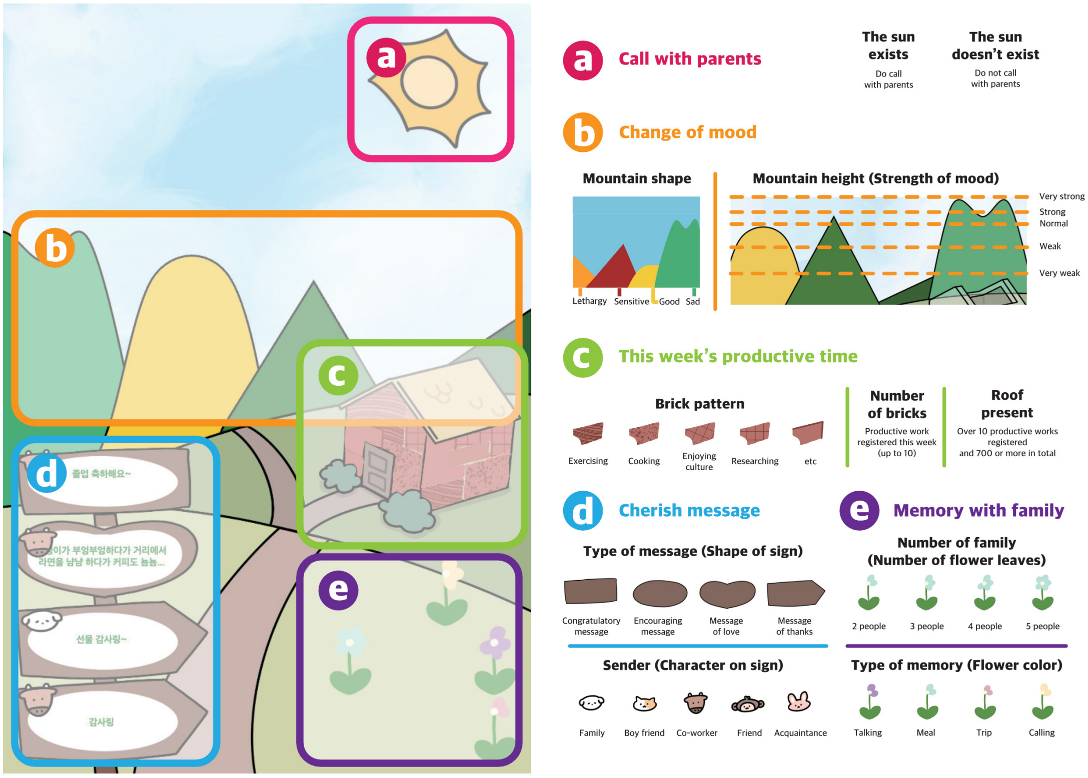


Appendix 2-2. P2's visual representation and change of contained visual variables based on tracking parameters;
P2 recorded about her 1) workplace atmosphere, 2) music listening and singing, 3) encountered number 4, and 4) today's coffee intake and it change rainbow, book on bookshelf, the brightness of lamp and coffee & coffee cups respectively.

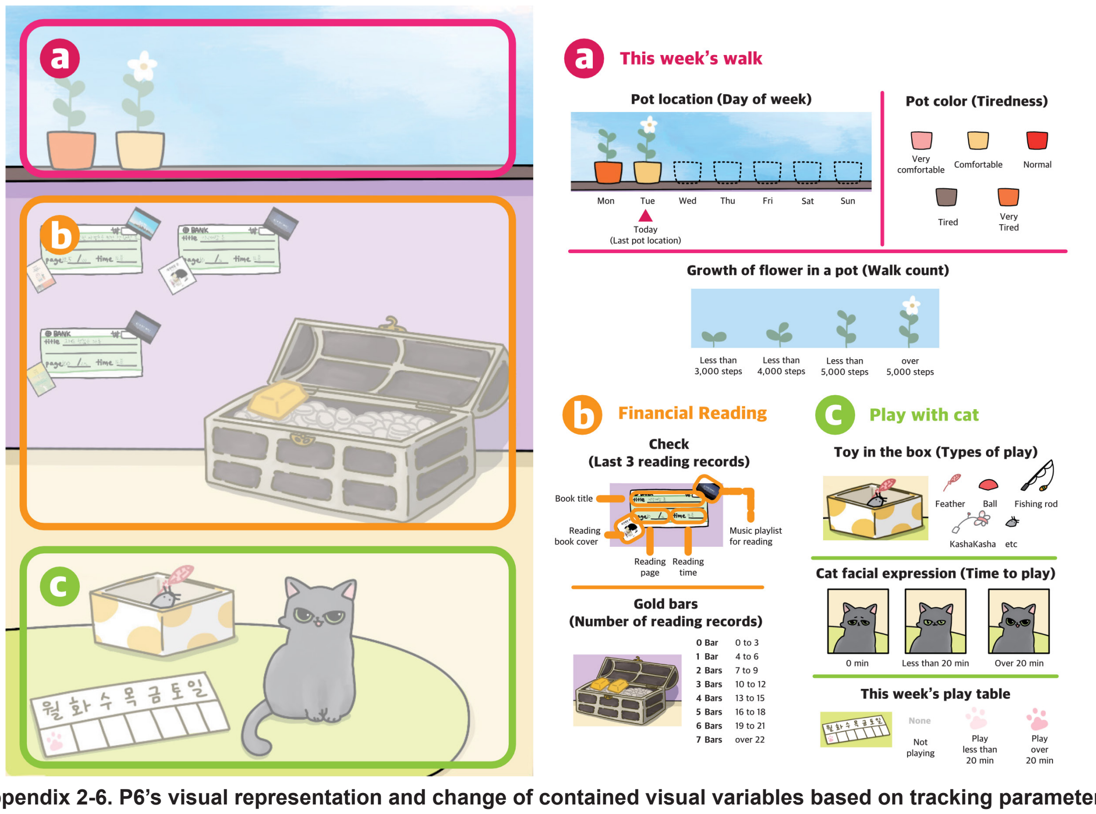


Appendix 2-3. P3's visual representation and change of contained visual variables based on tracking parameters;
P3 decides to track her 1) emotion, 2) luck, 3) walk, and 4) achievements, and these records cause the visual state change of weather, four-leaf clover pendant and flower bouquet, and rabbit doll in the above digital illustration.

Appendix 2-4. P4's visual representation and change of containing visual variables based on tracking parameters;
P4's tracking topics were 1) Time with acquaintances, 2) Recharging time, and 3) today's photo. spent time with acquaintances yields a change of clock time and place with acquaintances changing the landscape of the window. Based on recharging time the ink in the ink bottle was filled and recorded pictures were attached to a wall.



Appendix 2-5. P5's visual representation and change of containing visual variables based on tracking parameters; P5 records 1) change of mood, 2) cherish message, 3) productive time, 4) memory with family, and 5) call with parent and it changes state of ridge of the mountain, sign, house on construction, and flowers respectively.



Appendix 2-6. P6's visual representation and change of contained visual variables based on tracking parameters; P6's tracking topics involved 1) financial reading, 2) play with cat, and 3) walk and change check and gold in safe, cat & toybox, and flower in a pot.