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Patina Engraver: Visualizing Activity Logs as Patina in Fashionable Trackers

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ABSTRACT
Despite technological improvements in commercial activity trackers, little attention has been given to their emotional, social, or fashion-related qualities, such as their visual aesthetics and their relationship to self-expression and social connection. As an alternative integrated approach incorporating HCI, fashion, and product design, our project made use of the characteristics of *patina* to improve activity trackers as fashionable wearables. We developed the Patina Engraving System, which engraves patina-like patterns on an activity tracker according to a user's activity logs. Using a piercing technique, the patina of activity logs has been made abstract, visually rich, gradually emerging, and historically accumulated. During the field trial, we found that the patina motivated the participants to increase exercises for engraving aesthetic patinas. A tracker with patina triggered spontaneous social interactions in face-to-face situations. The participants also cherished the trackers that held their own history. Based on the field trial, we discuss design implications for utilizing patina in designing future fashionable technologies.

Author Keywords
Activity tracker; patina; fashion; digital fabrication.

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

INTRODUCTION

Recently, there has been a proliferation of commercial activity trackers for monitoring physical activity related to health and wellbeing, including Jawbone UP, Fitbit, Misfit Wearables, and others [23]. Most of the activity trackers collect an activity log and help users reflect on their life by visualizing the data in mobile or web applications. Related to tracking devices, the field of HCI has mainly contributed to practical issues such as how to improve sensing mechanisms and understand diverse self-monitoring methods [4, 5, 9, 26].

However, one of the important aspects of activity trackers is that they are personal fashion items that play a role in personal identity, visual aesthetics, and social communication that goes beyond technological features such as usability and sensing accuracy etc. [2, 28, 32]. Though activity trackers have been improved as a personal activity monitoring tool, it is necessary to consider issues related to HCI's third wave such as engaging user experience and the meaningfulness of digital artifacts [8]. Considering the way that activity trackers are worn in everyday life, it is especially important to investigate how they can be improved as fashion items. Since the majority of activity trackers are worn in a manner that makes them visible, customers inevitably consider not only their functionalities but also their visual appearance. Some companies have started to raise their competitiveness by cooperating with fashion brands because the technological aspects of trackers have become otherwise equivalent in the market [11].

As an alternative design approach to activity trackers, we focused on the intersection of HCI and fashionable product design. In particular, we were interested in the concept of *patina* in activity trackers. Figuratively, patina refers to any fading, darkening, or other sign of age that is felt to be natural and/or unavoidable [18]. It is known that artists and designers often deliberately use patina as a design resource for constructing aesthetic properties, lending credibility to an object or bestowing a "warm" feeling through art or product design [6, 37]. For similar purposes, we applied the concept of patina for designing activity tracking systems to improve the tracking experience of those who wear trackers to monitor activity.

In this paper, we present the Patina Engraving System (Patina Engraver and Patina Tracker), which engraves patina-like patterns on the wristband of activity trackers and thereby visualizes users' accumulated activity logs. Accordingly, the appearance of the trackers changes along with the users' tracking experience. Using the system, we conducted a field trial with 8 participants for 5 weeks to learn how the system was used in their lives.

This paper makes several contributions. First, it details a novel activity log visualization technique by applying the concept of patina. The Patina Engraving System is

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proposed as an example of an alternative approach to aesthetically represent an activity tracker. The process and rationale behind the system design are presented as design knowledge. The results of the field trial improve our understanding as to whether patina-like engraving enriches the tracking experience. Finally, it guides the design of future fashionable products with patina by suggesting design issues and opportunities.

BACKGROUND & RELATED WORK

This work is related to the research topics at the intersection of personal informatics and fashionable wearables. Regarding personal informatics, works on quantified-self with activity tracking and visualization of activity logs are particularly relevant. Diverse development cases also exist in the field of personalized activity tracking in fashionable wearables.

Quantified-self: General Use of Activity Trackers

The area of quantified-self movement has developed guidelines as to how to collect and use activity data, often from trackers and tracking applications [4, 5, 24, 25]. For instance, Rooksby et al. discussed various styles of tracking, including goal driven tracking and documentary tracking [30]. Li et al. found six kinds of questions that people ask about their data: Status, History, Goals, Discrepancies, Context, and Factors [25]. They also found that certain kinds of questions are more important depending on the phases of reflection: Discovery and Maintenance. The previous work in this domain contributed to our understanding of the practices of tracking systems. It emphasized the necessity of producing more than technological improvements in activity tracking, the importance of considering the emotional aspects of tracking, and the notion of developing social tracking beyond the ability to publish data to social networks [30]. Nevertheless, relatively little attention was paid to a wearable tracker. Specifically, this study takes a design approach to activity trackers as a fashionable item and attempts to improve their emotional and social qualities.

Visualization of Activity Logs: From Virtual Medium to Physical Medium

For supporting effective self-monitoring and motivating users to partake in physical activity, visualization has been a key issue in personal informatics. The majority of commercial trackers mainly target the virtual medium using numbers, graphs, and metaphors [10, 31]. Numbers and graphs take up little screen space and can be easy to interpret, however there can be usability and interpretation issues when it comes to larger data sets [36]. Some researchers suggested using virtual metaphors such as interactive art displays [9] or growing a pet according to the activity log [26]. Their research shows that this type of visualization can be engaging and fun.

Beyond the virtual medium, research has been carried out relating to the use of the physical medium for visualizing physiological and activity logs. For instance, Requena presented research projects to fabricate the physical medium as jewelry based on physiological data [29]. Related to the physical representation of activity logs, Khot et al. developed SweatAtoms, which transforms the physical activity data into 3D printed artifacts [21]. They found that a physical medium made people more conscious of their involvement in physical activity. Although the previous work showed the potential for utilizing a physical medium, there are limitations to deploying this approach in activity trackers and tracking systems. As explained in Khot et al.'s research [21], the building process using a 3D printer is a laborious and time-intensive process that is uncomfortable for general users. Additionally, because the physical object represents just one moment of tracking, users need to generate a number of objects for long-term activity logging.

In our study, we tried to exploit the advantages of the physical medium and reduce the burden of the building process. In particular, our work differs from previous research in that we exploited patina as a physical medium to visualize activity logs just as artists deliberately add patina for constructing aesthetic properties and simulating antiquity in newly-made objects.

Activity Trackers as Fashionable Wearables

The term *fashionable wearables* is used to refer to designed garments or accessories that combine aesthetics and style with functional technologies [32]. The embedding of electronics into fashion items has been investigated in research for many years, and there are even several commercial cases for supporting physical activity. Most of them mainly sense and transmit the wearer's physiological and movement data in real-time [1, 35]. As a research prototype, Social Fabric Fitness provides a glanceable shared screen on the back of a runners' shirt to increase awareness of group fitness performance [27]. Though several wearable devices have been designed to sense and monitor physical activity, they have been less than satisfactory on the fashion front. Like other wearable devices, activity trackers are generally designed as plain black (or single color) wristbands and look more like digital watch straps. To improve the quality of trackers as fashion accessories, some fitness tracker companies collaborated with luxury fashion brands [11]. Nevertheless, while the current design approach might improve trackers' visual appearance when they are worn, the design approach focusing on the visual appearance has little relationship with the main function of trackers such as activity tracking and supporting activity monitoring. Additionally, given the popularization of digital fabrication in the HCI field [20, 21, 36], there is now the potential to strengthen the diverse roles of a fashion item by allowing it to express a user's personal identity or improve social connections as well as visual aesthetics.

These cases illustrate the need for an alternative design approach that integrates activity log visualization in the area

of personal informatics with an understanding of activity trackers as fashionable wearables in the fashion and product design field. This integration is important not only for improving users' physical activity, but also for supporting and engaging user experience in the long-term. To exceed the current design approach, which focuses on visual aesthetics, this research explored a design approach that utilizes activity logs for making patina-like patterns.

DESIGN EXPLORATION

We exploited the concept of patina for visualizing activity logs physically and cumulatively. In what follows, we explain the characteristics of patina, our design exploration, and the rationale behind our decisions relative to the materials and technique used to create patina.

Visualization of Activity Logs in the Form of Patina

The word *patina* refers to a thin layer that forms variously on the surface of stone, on metals, and on wooden furniture (the sheen produced by age, wear, and polishing). It can also refer to any change a surface acquires through age and exposure [18]. Patina has been used to increase the value of artifacts in art and design. Today, the terms patina and patination are used in a broader sense, denoting techniques for applying processes connected with the ageing of the surfaces of works of art or the accumulated changes in surface texture and color that result from an object's normal use. Designers have intentionally used some materials on the surface of objects to leave patina that gives a sense of history [14, 17]. Specifically, according to literature on art and culture, the characteristics of patina can be classified as below [5, 18, 37]:

- **Abstract**: Patina provides information in ambiguous ways. The abstract and subtle shape of patina may stimulate users' reflection.
- **Visually rich**: Patina is often used to make an object look aesthetically pleasing. It is often expressed on the surface of the object by changing color or texture as shown in a leather product.
- **Gradually emerging** (on a physically limited surface): Patina is created gradually in a limited space on a surface. In the long term, the patina emerges, and its expression becomes thicker and richer.
- **Historically accumulated**: Patina shows the past history of an object's use. People may leave the patina intentionally to mark an event or person. Or the patina may be unintentionally generated while the object is touched or exposed to the environment.

The characteristics of patina have already been applied in the art and design area. Some cases exist in applications of graphical interfaces that metaphorically exploit patina to provide information about user history in the HCI area [19, 33]. Few cases exist for improving the quality of a digital device. We tried to utilize physical patina in tracking systems by visualizing activity data in the form of patina and applying the patina to tracking devices and systems.

Technique and Material for Engraving Patina

With consideration given to the characteristics of patina, we tested visualization techniques in a physical medium and materials to simulate patina. In particular, inspired by stippling [34] and tattooing, we explored a piercing technique that inserts a needle into the surface, which is attached to an oscillating unit (solenoid in our case). As the unit rapidly and repeatedly drives the needles in and out of the surface, the needles leave small dots on the surface.

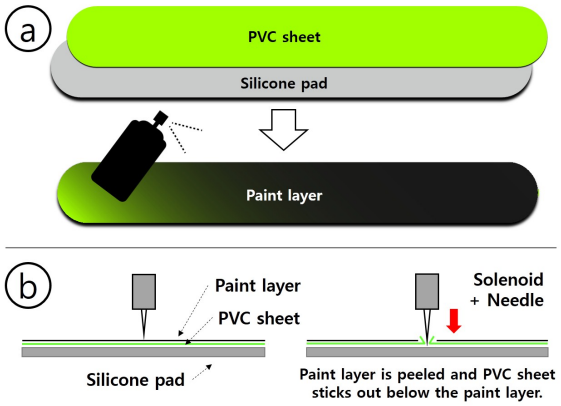

Figure 1. Material and technique for engraving patina

By exploring and comparing other fabrication techniques such as CNC milling, laser cutting, and 3D printing, we found the piercing technique has several advantages for visualizing patina. First, its expression is relatively noticeable in visual and tactile ways like the cases of tattoo or stippling arts. Second, it expresses patina gradually on a physically limited surface. Since CNC milling and laser cutting takes the surface away, and 3D printing makes the surface bigger, there are limits to the amount of patina that can be expressed on the same surface. On the contrary, piercing can express detailed and gradual traces on a limited surface. Third, the set-up and clean-up process of a piercing device is relatively convenient. CNC milling and laser cutting create lots of dust and they are risky for general customers. 3D printing takes a long time to construct objects and requires inserting materials continuously.

Throughout the process of exploring materials to pierce, such as a silicone pad, leather, etc., we developed material to maximize the visual and tactile effectiveness of the patina produced by the piercing technique (Figure 1.a). The developed material consists of three layers. The first layer at the bottom is a silicone pad (1mm). On the silicone pad, a brightly colored PVC sheet (125 μm) is attached. Then, as a third layer, a dark paint is evenly spread on the PVC sheet. When the needle reaches the painted surface, the painted layer is stripped down. This causes the bright sheet to stand out against the dark painted layer, making the pattern both visually and tactually vivid (Figure 1.b).

Visual Patterns of Patina

We also explored visual patterns for representing patina that reinforce characteristics such as *abstract, visually rich, gradually emerging,* and *historically accumulated*. Since the *abstract* and *visually rich* aspects are satisfied by the allocation of pierced dots while the *historical* aspect is satisfied by using users' activity data, we focused more on the aspect of *gradualness* on a physically limited surface.

To visualize patina on a physical surface, we applied stippling, a technique that creates a pattern simulating varying degrees of solidity or shading using small dots [34]. Throughout the exploration, we found that the piercing mechanism could be applied in three ways to our material to express the characteristics of gradualness and historicity (Figure 2). Although other types of visual patterns could be used to express patina, we selected the face, line, and fractal types that can be modified widely as basic components of visual patterns. These basic visualizing types were applied in our prototypes.

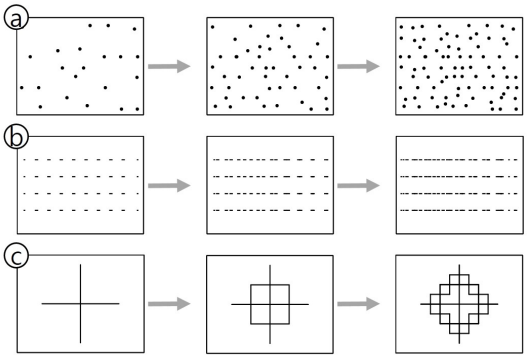

Figure 2. Visual patterns of patina: (a) Stippled face type, (b) Stippled line type, (c) Fractal type.

- Stippled face type: By filling a face with dots, it is possible to vary the color of the face.
- Stippled line type: By filling a line with dots, it is possible to make the line thicker and clearer.
- Fractal type: This type is related to a combination of lines. We especially utilized a fractal shape that is infinitely self-similar, iterated, and detailed theoretically.

PATINA ENGRAVING SYSTEM

Through the exploration of a piercing technique and material and visual patterns, we developed a prototype of the Patina Engraving System consisting of the Patina Tracker and the Patina Engraver.

Hardware of Patina Tracker and Patina Engraver

The Patina Tracker uses the three-layered material we developed in the wristband part (Figure 3). To fasten the band, magnets were attached inside at both ends. As a tracking sensor, we utilized the sensor part of Fitbit Flex [10], which was embedded at the center of the wristband. Additionally, an RFID tag was attached inside the band to identify the participant's ID and load their activity logs.

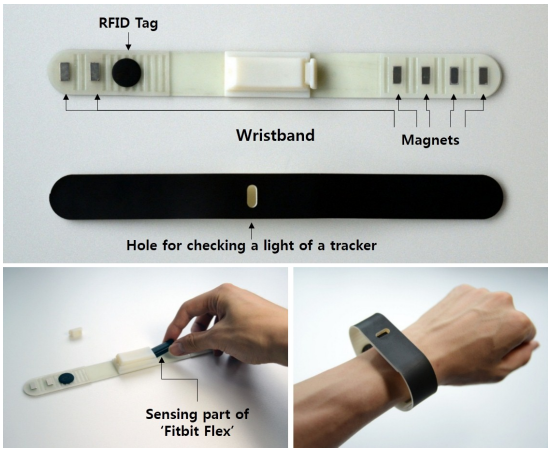

Figure 3. Patina Tracker

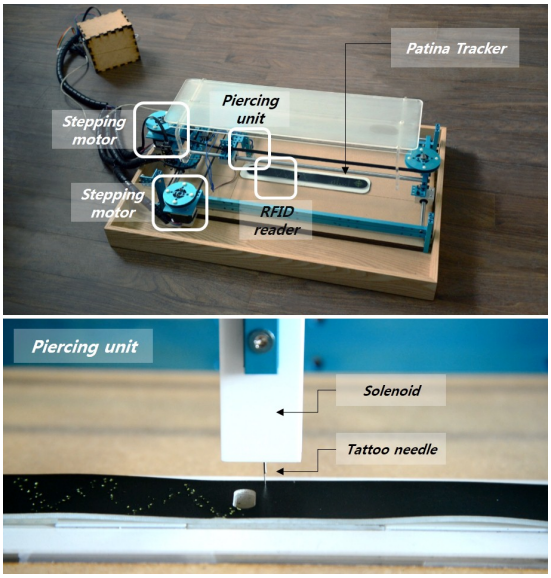

Figure 4. Patina Engraver

The Patina Engraver mainly consists of two stepper motors and a piercing unit (solenoid with a needle) (Figure 4). The piercing unit is moved in the XY-plane by two stepper motors. The piercing unit drives the needles up-down by the solenoid with the speed of 3-5 times per second. The diameter of the needle in the piercing unit was 0.35mm. During our exploration, it is found that the piercing speed and resolution vary depending on the speed of motors and the needle size. The rack at the bottom is used to place a tracker for engraving. When a tracker is put on the rack, magnets under the rack hold the tracker while it is engraved. At the same time, the RFID reader under the rack identifies whose tracker it is.

Software of Patina Engraving System

In this system, users' activity logs are periodically saved to the local computer by accessing their Fitbit account (Figure 5). If the Patina Tracker is placed on the Patina Engraver, the engraver identifies the user and loads his/her activity logs on the local computer using RFID. Then, the local

computer analyzes the activity logs and sends pattern codes to the Arduino board in the Patina Engraver. The engraver moves the stepper motors and the piercing unit based on pre-defined pattern types and the pattern codes from the local computer.

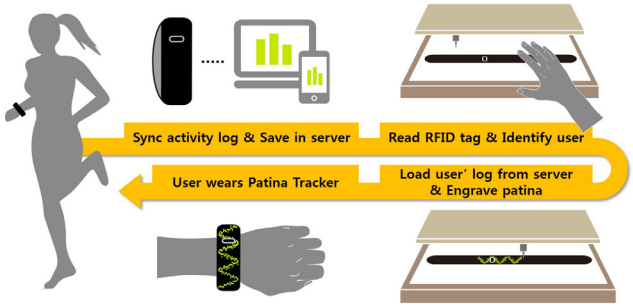

Figure 5. System overview

Patterns on Patina Tracker

The overall layout of the patina patterns on an activity tracker was decided through several phases of exploration. Firstly, we selected (i) the types of activity logs as the source data for engraving patina. Among diverse types of activity logs, we chose *steps*, *active time (minute)*, *activity calories*, *time in bed (minute)*, and *total walking distance (kilometer)* that people generally want to know when using tracking systems. Then, we considered (ii) shapes for each activity log such as zigzag, rectangle etc., (iii) visual patterns for engraving patina in the limited space (stippled face type, stippled line type, fractal type), and (iv) physical location on the surface of trackers. The pattern layout on an activity tracker was evaluated by noticeability, possible number of engravings, and visual aesthetics. Finally, each source data was mapped onto four zones (Figure 6).

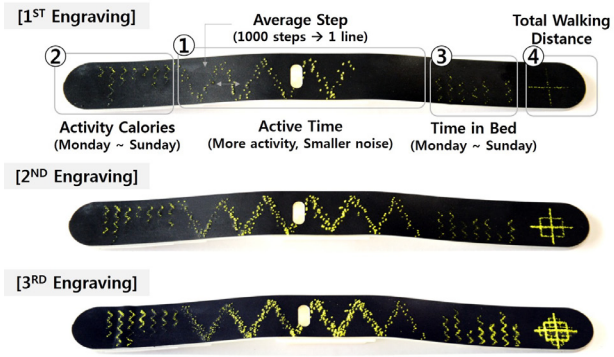

Figure 6. Designed patterns on Patina Tracker

- **Zone-1**. In this zone, average steps and active times per day are mapped to the zigzag line and engraved in the stippled face type to cover the middle surface of a tracker. Since this zone is most conspicuous when the tracker is worn, it was chosen as the area to receive steps and active times as source data. In detail, steps are mapped by the number of diagonal lines. Considering the length of the tracker and the notion that 10,000 steps a day is normal, we decided to map 1000 steps as one diagonal line. Then active times are used to define the noise on the lines. Specifically, when the active times are long, the noise value becomes smaller to engrave a more clear and vivid line. When the active times are short, the dots are engraved sporadically with bigger noise values along with diagonal lines.
- **Zone-2**. In this zone, calories per week are mapped to the length of each zigzag line. From the left to the right, the length of a line indicates the amount of activity calories from Monday to Sunday. Due to the narrow space, the stipple line type was used for engraving.
- **Zone-3**. Like Zone-2, we mapped time in bed to each line. To magnify the differences among days, patina lines were engraved when the time in bed is in the range of 240–540 minutes.
- **Zone-4.** In this zone, we mapped total walking distance using the fractal type to show distinct improvement. We divided total distance into 3 levels (lv.1: 0–20km, lv.2: 20–40km, lv.3: 40–60km). When total distance reaches a certain level, a more detailed fractal structure is drawn in three phases.

In the Patina Engraving System, the entire engraving process took about 5–10 minutes depending on the participants' activity logs.

FIELD TRIAL

We conducted an "in the wild" study [3] to understand the impacts of visualizing activity logs using patina not only on functional aspects, but also on the emotional and social aspects of the tracker and tracking experience. When participants used the Patina Engraving System, we expected that a certain amount of time would be needed for them to grow accustomed to using the new device. We also expected to find various roles of the patina engraving process and the trackers besides the natural uses. Therefore, we installed the Patina Engraver and Tracker in a natural environment for 8 participants for 5 weeks. The sample size and the length of the field trial were determined from a previous study [3] that discussed field trial methods. Given the exploratory nature of our design work, we focused on gathering a rich set of opinions rather than quantitative findings. As such, our work can be characterized as a form of cultural probing [16] and an "in the wild" study that aims to encourage reflective thinking about a system.

Participants

We contacted sports clubs to recruit a group of participants because we expected that they would be interested in exercising and activity tracking and would have a close relationship with each other. As recommended from a previous study [15], the intimate relations among participants at the same club could be a stimulus to expressing their opinions and providing a greater depth of understanding about the field context. Eventually, eight participants from the same sports club (a badminton club) were recruited for our study. There were 5 male and 3 female participants with ages varying from 22 to 28 years

(M = 24.1, SD = 2.2). All participants played badminton more than twice a week together and had close relationships. Three of the participants partook regularly in other sports such as walking, football, or golf. Participants' past experience of using trackers was also considered in the recruitment phase. Three participants had an experience of using trackers for about 1 month (M4: Misfit Shine, F1: Galaxy Gear Fit, F2: sleep tracking application). We expected that the past experience of using trackers would be useful for eliciting the potential value of our system. Throughout the paper we refer to each participant by sex and the week of the interview session (e.g. M5, week 3).

Method

During the field trial, the Patina Engraver and Trackers were used for 5 weeks. To lessen the participants' burden and observe how the system pervaded their normal lives, the Patina Engraver was installed in a building which all participants could reach within 10 minutes by foot; it was also close to the gym where the participants play badminton. After starting the study, participants were asked to set up their trackers and applications. They then created a Fitbit account with an ID and password we assigned them. Using them, we could access participants' raw activity logs. Participants were allowed to sync their logs as desired using a personal computer or mobile phone.

During the first week, participants wore the tracker without engraving patterns. Participants adapted to the tracking process and this period reduced the novelty effect of tracking itself. The first week's interviews included questions related to their biographies (ordinary practice of exercise and sleeping).

During the 2nd to 4th week, the participants visited us for interviews and used the Patina Engraver twice a week. Depending on their schedules, we met with them at intervals of 3–5 days. Among the two meetings per week, one was only for engraving and the other was for interview and engraving together. The interviews were conducted with a group of two or three participants. Since they had close relationships and attended the same sports club, they could discuss their experience spontaneously [15]. During the interview, we asked questions relating to the role of the patina and the functional, emotional, and social aspects of the Patina Engraving System. About the social impact, we asked how our system was used among acquainted and non-acquainted people.

In the 5th week, we stopped engraving tasks and participants wore a normal Fitbit tracker. In the post-use interviews, we asked what they missed the most while using the Patina Engraving System and the impacts of the engraving system compared to normal trackers. In addition, we asked them about the possibility of using patina in other contexts.

Data Collection and Analysis Method

We mainly analyzed the results based on the weekly and post-use interviews. The weekly photos of participants' trackers and their activity logs were used to identify the detailed situations users mentioned in their interviews. All interviews, for a total of 720 minutes, were audio recorded and transcribed. Interview transcription and contextual use data, including activity data and photos of participants' trackers, were categorized by our research team through iterative analytic induction. During the analysis, we considered the novelty effects and found unexpected uses and unreported results from the lead participant by referring to existing research [3].

FINDINGS

Overall, participants were receptive to the idea of engraving patina and were engaged with using their Patina Trackers and Engraver. Table 1 shows how the trackers were used for 5 weeks. The activity logs varied depending on each participant's tracking style. We also found that participants frequently forgot sleep recording, which required a mode change in the tracker. However, in general, participant's average amount of steps, active time, active calories, and time in bed tended to decrease after the 1st week as the tracking system became ordinary to them. From the weekly interviews, we also confirmed that participants become familiar with activity trackers: *"Though it was interesting to monitor my data at first, I got used to it after using the tracker several times. Now I am monitoring it less frequently than the 1st week"* (M3, week 2).

	Week 1	Week 2	Week 3	Week 4	Week 5
Steps per day	8816.3 SD = 3889.1	8688.5 SD = 3036.8	7677.4 SD = 2660.6	9085.8 SD = 3058.5	6056.2 SD = 2751
Active Time (min.) per day	81.2 SD = 33	63.5 SD = 40.1	59.1 SD = 20.9	66.6 SD = 21	52.3 SD = 23
Active Calories per day	776.4 SD = 327.2	779.2 SD = 319.7	718.6 SD = 263.7	829.9 SD = 246.1	582.4 SD = 371.2
Time in Bed (min.) per day	322.4 SD = 110.7	290.2 SD = 156.8	210.8 SD = 119.7	216.8 SD = 116.1	243.3 SD = 147.2

Table 1. Average activity logs during 5 weeks

Figure 7. Participants' Patina Trackers at 3rd week (after engraving 3 times)

Meanwhile, we could observe that participants' Patina Trackers became varied after 5–6 times of engraving

(Figure 7). For instance, while the trackers of F1 and M1 were engraved with thicker patina patterns, those of M3 and M4 had less clear patina due to their relatively low level of activity. Likewise all participants' trackers became distinguishable. Next, we explain the functional, emotional, social impacts of patina engraving on the tracking experience and the perception of trackers as fashionable wearables.

Wondering about What Patina Means and Past Activities

One common feature of commercial trackers is to provide an activity log using mobile and web applications. Unlike applications that show prompt changes in physical activity, the abstract and historical aspect of patina on the trackers provided summarized information about past activities in a subtle way. After patina was engraved on the tracker, participants became curious about which parts of the tracker had changed and what kind of new patina patterns had appeared. They then tried to associate the patina with their past activities using mobile phones in the interview sessions: *"(While looking at Fitbit app) Maybe this part is vacant because I did not sleep enough for working overtime"* (F2, week 2).

During the interviews in the 4–5th weeks, several participants mentioned that they checked their activity through the mobile app or website less frequently and their activity checking period became longer as they got used to tracking. In this situation, the patina tracker became a supplement for providing summarized information: *"It became bothersome to check my activity log in mobile app. In that sense, I like this patina because it expresses approximate lifestyle"* (M3, week3), *"Though it is difficult to figure out accurate information, this provides indirect proof of my activity like a growth ring"* (F1, week 3). Several participants said they did not need to check detailed information through the app or web because they were able to expect a general tendency even without them. For them, patina was enough for checking their general life cycle.

Meanwhile, some participants mentioned the limits of patina for delivering information. Although patina could deliver information about how their activities had changed, they mention that it was not suitable for informing them about detailed changes such as differences among days or weeks: *"Because it is hard to figure out the difference as more and more patina is accumulated, it will be not good to understand my activities per day"* (F2, week 2).

Feeling Pressure for Engraving Aesthetic Patina

The patina and patina engraving put persistent pressure on participants to exercise and wear a tracker. We observed that participants made an effort to engrave more aesthetic and meaningful patina patterns. In our system, as steps and active times increase, the zigzag shape in Zone-1 is engraved more thickly in the middle of the tracker and participants considered this to be more aesthetically pleasing (Figure 6, 7). Consequently, participants were motivated to increase their exercise. Though the response about ugliness was not intentional, it seemed because vivid and flawless patterns are generally regarded as beautiful in commercial digital products. Additionally, since the patina was indelible and the engraving affected the entire aesthetics of the tracker, participants were conscious about this and mentioned that they tried to exercise more in their daily life, walking a longer route or using stairs, etc. In the case of F1, she thought her patina was ugly due to her short exercising times after the 1st patina engraving. During the next week, she mentioned that she tried to work out harder to create a more beautiful patina at the next engraving: *"Because this tracker is directly affected by my loose activity and showing it physically, it makes me regret my insufficient exercising"* (F1, week 3).

While the physical presence of patina put psychological pressure on the participants, patina engraving could also be regarded as a reward for their activities. Some participants felt fulfillment when they looked at their patina-accumulated trackers during the three weeks of patina engraving. The fact that the patina resulted from their physical activities was especially fulfilling, as they felt that the aesthetically-evolving patina was a reward for their efforts: *"If I run longer, the patina will increase and become thicker, which make me feel proud of my efforts"* (M3, week 2), *"What about using this system in the gym? If people engrave patina after working out for a week, they would feel rewarded"* (F2, week 3).

Furthermore, we found that the patina engraving affected tracker wearing habits as well. Participants were concerned about the fact that if they did not wear their trackers constantly, the patina would be irrelevant to their general lifestyle: *"Compared to other tracking devices, I tried harder to wear it regularly. This was because it is better to make patina which correspond to me"* (M4, week 2).

Having Spontaneous Co-located Interaction

Existing tracking systems support online communication by posting an activity log in social network services, showing a friend's activity log, and providing chatting functions, etc. However, in our study these functions were used less frequently at the end of the study compared to the 1st week. Most participants felt reluctant to reveal their activity history to the public. For them, it felt like vanity. Also, as they were already using other chatting platforms, they did not require that in our tracking application. Our system is different to the prevalent systems in that activity information was shown in the physical world without using a virtual medium. Using this system, participants were able to reveal their activity history quietly in the physical world. Accordingly, we observed that spontaneous interactions emerged in face-to-face situations.

Sharing and Comparing within the Participant Group

Within the participant group, which met frequently in daily life, the physical presence of patina allowed participants to access each other's activity logs easily. They said that the Patina Tracker was suitable for situations in which they

exercised with sports club members in the gym without using mobile phones for accessing their activity log. Though the abstract shape of patina made it difficult to recognize details at a glance, it induced them to compare other participants' patina with their own. F1, F2, and M4 mentioned that they envied M1's tracker and were motivated and inspired by it. *"When we met in the sport club in the 2nd week, I found that Dave (M1)'s tracker was prettier than mine. And I wanted to make mine like his"* (F1, week 2). In this way, participants shared other participants' information about activities in physical spaces.

Getting Others' Attention & Conversing about Patina

Besides the social impact of patina within the participant group, we also observed social impacts on people who do not know the meaning of patina. For them, the Patina Trackers attracted attention due to the evolving nature of the accessory and the different patina that emerged periodically, thus differentiating them from static accessories. M1 said that the normal trackers, which were worn during the 1st week before the patina engraving, also attracted others attention. However, he said that in the case of the normal trackers he could only talk about the functional features of the trackers rather than personal activities related to tracking. On the other hand, the Patina Tracker with accumulated patina enabled communication about stories behind the patina and their physical activities among the people who did not know what the patina meant. In particular, participants could tell personal stories of events, growth, and achievement while exercising or sleeping: *"My colleagues ask me why the patina changed. Then I explained about each patina by associating the patina pattern with my daily activities"* (M1, week 2).

In addition, they mentioned that the abstract shape of the patina had the advantage of hiding private information from strangers: *"For people who do not know this tracker, they will consider it as just a wristband. Rather than engraving numbers or graphs, this abstract shape of patina is proper not to give details of my life"* (M4, week 4). They said they would not want to disclose their activity log to strangers.

Crafting a Symbolic Object that Holds One's Own History

All of the participants enjoyed the patina engraving process. Compared to normal tracking services, they said the engraving provided a fun experience. By actually allowing participants to engage with the patina engraving process, it promoted a sense of engagement: *"I think this engraving is similar to stitching-up in the sense that the patina emerges as I walk more"* (F1, week 4).

However, we observed that their interest in engraving faded over time, whereas their interest in the trackers lasted longer. In the interviews during the 1st week before the patina engraving, many said they would cherish their digital log more than the tracking devices. Nevertheless, through the patina engraving, they began to feel attachment toward the trackers, which contained personalized patina patterns and unique appearances. Accordingly, participants considered the Patina Trackers symbolic objects more than just a pedometer: *"If this tracker is lost and I have to get a new one without my patina, I would feel sorry about that"* (M5, week 4).

Meaningful attachment can emerge through the process of self-extension, where someone attributes important aspects of his or her self to an object [22]. In this system, the process of patina engraving helped users customize the tracker based on their activity log, which led to users symbolically extending themselves into the tracker and constructing autobiographical values: *"It (patina) is like my fingerprint. It is special in the fact that it shows who I am"* (M2, week 4), *"While patina make my tracker prettier, at the same time it strengthens symbolic meanings that I am training hard or living life to the full"* (F3, week 3).

DISCUSSION

Design Implications for Fashionable Trackers Using Patina

All fashionable items have physical, psychological, and social functions [2]. As found in our study, while aesthetically pleasing visual appearance is an integral part of fashionable trackers, it is also important to consider its psychological and social impacts, including self-expression, communication in social groups, and user experience around the trackers. In this section, we discuss research and design implications to improve the use of patina for making fashionable activity trackers.

Modifying Patina for Personally Meaningful Trackers

In our studies, participants liked the patina engraving process that customized a tracker based on their activity log, and they agreed that the patina contributed to making the tracker personally valuable. In the interviews during the 5th week, we discussed the further possibility of improving the current system to make a more meaningful tracker.

First, the selection of personally interesting types among diverse activity logs might contribute to making personalized trackers. For instance, M3 paid more attention to logs about sleep cycle, while F1 was interested in her sedentary time. Also, interpreting activity logs according to users' different lifestyles may create more meaningful trackers. In our prototype system, longer or thicker patina patterns were engraved in proportion to the absolute value of the activity logs (steps, active time, calories, time in bed). However, the same activity logs can be interpreted differently to provide meaningful information. For example, F3 wanted to engrave patina based only on the log of a specific day of the week when she took exercise regularly. If users are able to set the scope of the activity log—specific days, time slots per day, etc.—and the system utilized these to engrave patina, the tracker with patina patterns may be able to show more personal stories about their lives and deliver more useful information.

Moreover, since people have different goals when it comes to activity tracking, the patina might need to be engraved differently to meet their needs. For some users, walking

10,000 steps per day might be enough, whereas for others it might be insufficient. If the patina is engraved in proportion to the individual goals users set, the users are more likely to feel fulfilled or reflect on their lack of activities.

Using Patina for Sustained Engagement with Activity Trackers

Since activity trackers are used over a long period, designing a strategy to ensure sustained engagement is the key to their success. According to Fogg, a user needs to experience a feeling of progress toward defined goals to achieve sustained engagement in activity trackers [12, 13]. He mentioned that the success from achieving several smaller goals provides the positive momentum necessary for achieving bigger goals. In that sense, though our Patina Trackers could summarize how participants' activities changed over time, they had limitations regarding their ability to maintain users' interests and show their progress. Thus, it is necessary to consider ways of utilizing patina to motivate users in the long term. During the interviews, one of the frequently mentioned solutions for sustained use of activity trackers was to strengthen the impact of patina as a reward for completing small goals. For instance, it would be possible to engrave patina in special shapes when achieving a 100 km distance or accomplishing 20,000 steps in a day. M5 said that patina might be engraved in a way that a specific image becomes clearer gradually, which might provide a feeling of completion in the end. In this way, people would be able to gain the momentum necessary to progress. Thus, in future work, it is necessary to investigate whether the patina engraving as a reward can support sustained engagement in the trackers.

Adjusting Social Translucence of Patina

Erickson and Kellogg argued that social translucence is necessary in the digital domain [7]. As translucent property in the physical world supports graceful human-human communication in face-to-face situations, socially translucent systems can make users structure social interaction with each other and carry on coherent discussions. They worried that neither of these dimensions of social translucence are a given in the digital domain. In that sense, our system supported social translucence by engraving physical patina based on a digital activity log. By allowing users to see each other's trackers and their engraved patina and make inferences about their physical activities, the system extended the space of social interaction from the digital environment into the physical environment.

Considering the social translucence of the Patina Tracker and its effect, we could find further opportunities to develop the Patina Engraving System focusing on co-located physical activity. One of the significant qualities of the Patina Tracker is its social communication in physical space. During the last interview about the improvement of our system, several comments related to the use of the tracker for a specific group of users. For instance, M4 and M5 mentioned the patina could be engraved using both group and individual data—for example, the amount of time they exercise together or a comparison of the value of the group's activity level with that of the individual etc. Likewise, if we use this system for specific group activities, the patina on trackers may act as an emblem of the group and accordingly may strengthen peer relations and support sustained group activities.

However, it is necessary to continue exploring suitable types of information the patina can provide as well as the degree of social translucence. In our study, the Patina Engraving System visualized steps, active time, activity calories, and time in bed into the abstract shape of patina. Though the participants mentioned that the visualization in our study was fine to show to the public, they said that they would have hated it if the visualization showed details such as exact times. For example, if the tracker is too obvious, a user might feel shame about his or her lack of exercise and might worry about privacy. Since the patina would be readable for everyone including strangers, this highlights the need to tailor the types of information the patina provides, as well as the level of translucence based on the sensibilities and privacy concerns of the user.

Applying Patina to Other Contexts

Participants gave several ideas about the use of patina in devices other than activity trackers. They suggested that the patina might be helpful to achieve general health related goals like losing weight, rehabilitation exercises, or quitting smoking. M5 mentioned that people might feel a burden by exposing their smoking data to others by engraving patina on a Zippo lighter. He expected that other people would be interested in the evolving patina and support not smoking. Likewise, in future work we need to explore further whether the engraving of patina based on health relevant data can motivate people to achieve diverse health related goals and help them change their behaviors in the long term.

Also, we see opportunities for applying patina in other contexts. For instance, M3 said that it might be good to engrave patina on a credit card to warn card holders about excessive consumption. He said the patina on the credit card might force him to reflect on his spending habits. F2 mentioned that she wanted to leave physical patina on her radio that shows favorite channels. Her idea was that patina could accumulate around the tuning dial as the user frequently tunes into favorite stations. As mentioned by the participants, our design approach to combining patina with data about a user's history can be applied generally in product and interaction design. However, since the way of using various devices, users' needs, and the types of logging data differ among several cases, further research needs to be carried out to explore how patina can be applied in general interactive product design.

CONCLUSION

Our motivation for conducting this study was to make fashionable activity trackers that generate an engaging experience. Thus, in this paper, we have presented a new

design approach for activity trackers by visualizing activity logs in the form of patina. Also, with the deployment of the Patina Engraving System through an "in the wild" study, we explored how participants' activity tracking experience could be affected through patina engraving. We expect this research to inspire designs for diverse tracking devices and services, as well as general fashion and product designs.

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