

Patina-inspired Personalization: Personalizing Products with Traces of Daily Use

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ABSTRACT

Despite the popularization of product personalization systems, it is difficult for people to personalize a product in a way that symbolizes themselves and their daily lives. Borrowing the characteristics of patina generation, we suggest *patina-inspired personalization* as an alternative approach. This approach is a way of progressive personalization through transforming digital traces of product use into patina-like material traces on a product. As an exemplar, we developed *Trace-Marker*, a custom-built laser engraver for bicycle riders. It engraves aesthetic patterns on a bicycle bag according to a user's bicycle journey. During the field trial with 10 participants for three weeks, participants used the system to add symbolic meanings, in particular their unique identities and personal stories on their bags. The permanently engraved patterns enhanced the emotional bond with the bags. Based on the field trial, we discuss implications for improving patina-inspired personalization in wider contexts.

Author Keywords

Product personalization; patina; trace; symbolic meaning; self-expression.

ACM Classification Keywords

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

INTRODUCTION

Product personalization is a process that defines or changes the appearance or functionality of a product to increase its personal relevance to an individual [3]. The motivations for product personalization are related to people's desires to express themselves, be creative, or make items they cannot buy [25]. These days, falling costs for fabrication machines and a growing number of customization services make it cheaper and easier for people to make their own physical products [14,45].

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Despite the popularization of product personalization systems, there are some concerns regarding systems that focus mainly on the convenience of manufacturing a new object and improvements in the speed and accuracy of manufacturing. One concern is that it is still difficult for people to personalize a product in a way that conveys symbolic meanings of self-expression to the owner. In design and market research, a considerable number of studies have demonstrated the importance of symbolic meanings with respect to product design. This importance of symbolic meaning can be understood by the notion that products often act as a self-expressive means for people, providing personal meaning and communicating the owners' personal identities and narratives to others [6,16,30]. However, although people are able to easily participate in personalization through user-friendly interfaces in current systems, personalization still requires substantial design capacities so that a personalized product can symbolize the users' identities or lifestyles.

Because most product personalization systems are focused on a product's functional or aesthetic elements, it is challenging for users to include the intangible symbolic meaning in product personalization process.

To support general users' product personalization in a way that enriches a symbolic meaning about themselves, we tried to explore an alternative personalization approach by applying the characteristics of patinas. Figuratively, a patina refers to any fading, darkening, or other sign of age on an object that occurs through a natural or artificial aging process [17]. Artists and designers often deliberately use patinas as design resources for constructing aesthetic surfaces and for lending credibility or giving a warm feeling to an object [8,50]. Besides their aesthetics, patinas are valued for the ways in which they evoke the lived past [10]. For example, for patinas on everyday products such as denim jeans or antique furniture, the process of patina generation relies on the use of the product over time. Therefore, products exhibiting clear traces of use betray some characteristics of the users and how often, when and in which ways they were used.

Borrowing the characteristics of patina generation and digital traces together, we suggest *patina-inspired personalization*. Patina-inspired personalization is a way of personalizing a product through users' trace accumulations during the product's use stage. Inspired by how products become personalized with patinas, this approach supports progressive personalization during a product's use stage rather than

instant personalization at the manufacture stage of a product's life cycle [1,48]. Through an interactive personalization system, users can transform digital traces about product use into patina-like material traces on a product. As an exemplar, we present *Trace-Marker*, a patina-inspired personalization system that engraves patina-like patterns on a bicycle bag based on a user's bicycle-riding history, which is digitally recorded. Accordingly, the appearance of the bicycle bag evolves along with the user's history of bicycle-related experiences. We conducted a field trial with 10 participants for three weeks to learn the impact of patina-inspired personalization.

This paper makes several contributions. First, it details design considerations regarding how to support product personalization for enriching symbolic meanings of self-expression by applying the characteristics of patinas. *Trace-Marker* is proposed as an exemplar system for patina-inspired personalization. Primarily, the results of the field trial improve our understanding of how patina-inspired personalization is embedded in the context of product use while enriching the symbolic meaning of a product. This study guides the design of future product personalization by suggesting design issues and opportunities.

RELATED WORK

Product Personalization and Symbolic Meaning

As a self-expressive means, a product enables owners to communicate their personal identities and narratives to others [6,16]. The main reason why people pay attention to a product's symbolic meaning is that they want to enhance and express their self-concept: a person's identity and ideal image of him/herself [24]. As strategies for designing products' self-expressive values, several studies suggested personalization [30]. Meanwhile, as a response to DIY trend and product personalization, previous research in the HCI field has mainly been focused on making personalization accessible to a wider audience through parametric interface [22,34], gesture-based interface [11], mixed reality [47], etc. Despite improvements of the interfaces for modifying products' appearance or functions, it is difficult for general users to make personally meaningful products, which symbolize the users' identities and lifestyles.

Product Personalization with Digital Traces

Making a Souvenir-like Object Based on Digital Traces

There has been research on making personal objects by using digital traces such as activity data or physiological data. Data sculpture is a representative example that shows how designers and artists use digital traces for product personalization [38,51]. Moreover, in previous studies fabrication systems have been installed at home or in public contexts such as museums or conferences to make personal objects based on digital traces [23,31,32,37,43]. In these studies, the systems are used to make souvenirs that represent personal histories regarding physical activities, or activities at an art exhibition or conference. These studies illustrate the value of embedding digital fabrication in everyday contexts

to facilitate social interaction and users' reflections upon their activities. Our work is distinct from these studies in that we used digital traces for progressive product personalization. Unlike previous cases, which have made separate data-things [32], our study used digital traces of products so that the products could be personalized gradually according to users' histories with them.

Attaching Digital Traces to Physical Objects

Several researchers have taken an interest in improving the emotional value of physical objects by attaching digital traces to them. For example, Spyn [39] allowed people to leave digital traces, such as audio/visual media and geographic data, on fabric. Similarly, Broken Probes [20] and Chiocciola [15] used material traces, such as cracks, as mediums for connecting digital traces. As was done in previous work, we tried to exploit the advantage of the sentimental value of digital and material traces. The main difference between our study and prior research is that our approach is not about attaching digital traces but about transforming digital traces into material traces on products. Using this approach, we explored the possibility of personalizing a product as a self-expressive means.

Product Personalization from the Perspective of Product Life Cycle

The product life cycle comprises three stages: manufacture, use, and disposal [1,48]. The manufacture stage involves producing new products. The product use stage is when products provide services to users and when users interact with the products. The disposal stage describes the process of discarding or recycling the product. Most product personalization to date has been largely focused on the manufacture stage. The central research issues with respect to this stage include how to make an object with various materials and mechanisms [28,36] and how to make effective use of resources [27,40].

Unlike previous studies, we focus on personalization at the product use stage to enhance a product's symbolic meaning about the users and their experiences with a product. The main reason is that the product use stage is when users have the most active interactions with products and spend the longest time making histories with their products. Also, according to previous research on emotional durability and product attachment, the gracefully aging surface of a product, narratives with a product, and histories with a product can become salient factors for giving a product symbolic meanings [12,30,35,46]. These cases illustrate the potential for an alternative personalization approach that grows traces on product in a way that allows users to enrich the symbolic meanings of a product.

DESIGN EXPLORATION

We exploit the concept of patinas as an alternative product personalization, focusing on the product use stage and symbolic meanings. In the following sections, we explain how patinas' characteristics add value to objects and the rationale for patina-inspired personalization.

Values and Characteristics of Patinas

The word *patina* refers to a thin layer that forms on the surface of stone, metal, or wooden furniture. In a broader sense, it refers to any accumulated material traces from normal use of an object. Artists and designers have deliberately added patinas as part of the original design for constructing aesthetic, historic, authentic properties [8,49]. In addition, several studies have mentioned symbolic values of material traces and patinas that deliver unique narratives regarding an object [15,20,35].

Literature on art and culture illustrates that the value of a product's patinas is deeply related to the distinct characteristics of patina generation [8,17]. First, the process of patina generation relies on product usage over time. Depending on how they are used, some products may gather extensive patinas within a short period of time, and others may gather patinas more slowly.

Second, a patina is mainly determined by how, when, or where the product is used. The patina could be unintentionally generated by users' physical touch while the product is used. A person may also leave an intentional patina to mark a special moment during a product's usage (e.g., travel labels on a suitcase or dog-eared pages in a book). In these cases, patinas contain the information about the history of a product's use.

Lastly, the expression of a patina is abstract and emerges gradually. A patina is primarily valued for its aesthetic expression. Also, due to its abstract nature, a patina provides information about past product usage in ambiguous ways. The abstract and subtle shape of a patina can be means of reflecting users' pasts.

Some applications of graphical interfaces in the HCI area have metaphorically exploited a patina to provide information about user history [18,19,42]. However, few ways have been studied for improving the quality of physical objects through product personalization enriched by patinas. Although the Patina Engraver system showed the potential for utilizing the characteristics of patinas to visualize activity data on wearable devices, the users' involvement in selecting traces and designing was limited [26]. In particular, our work differs from previous research in that we tried to suggest a new way of product personalization and support users' modifications of everyday products based on traces of product use.

Design Considerations for Patina-inspired Personalization

Based on review of existing product personalization systems and understanding of how patinas' characteristics add value to objects, we derived the following design considerations for patina-inspired personalization. These considerations are related to timing, source, expression and process of product personalization.

Supporting Progressive Modifications during Product Usage

In the natural environment, patinas are accumulated over several physical touches, becoming clearer over time. The

progressive change gives a product historical value. Inspired by this process, we conceived a personalization system that progressively modifies a product during long-term product use. Thus, rather than manufacturing a new object or completing personalization at once, patina-inspired personalization would enable progressive and repetitive modifications of the same product. Through repetitive operations, users would be able to gradually personalize the product by modifying parts of it.

Utilizing Digital Traces of Product Use as a Source of Personalization

Though several personalization systems have been improved and have become accessible even to lay users, most systems still require design capabilities from planning to production. To support general users' personalization with symbolic meanings, we were inspired by the fact that patinas are naturally generated from past experiences, which can become a source of design. Recognizing that patinas are mainly caused by product use, we tried to create a personalization system that utilizes digital traces: histories of product use that can be digitally recorded. Of the many types of digital traces, we focused on the data that may jog a user's memories about his/her past experiences. According to Doménique et al.'s study, during everyday life, people rely on ordinary physical objects for the retrieval of memories, and people think of locations and activities associated with such objects [13]. Thus, we decided to use digital traces that can remind users of how, when, and where a product was used as a source of personalization.

Generating Abstract but Aesthetic Traces on a Product

Traditionally, designers have valued patinas for their abstract but aesthetic expressions. Moreover, the abstract shapes of patinas provide subtle information about the past [8,49]. Considering the advantages of patinas' expressions, we conceived a personalization system that engraves abstract and aesthetic material traces on a product based on digital traces. Instead of using numbers or letters, we tried to generate material traces that were arranged in geometrical patterns through a computational design. In particular, by mapping a user's digital traces through predefined pattern-generation algorithms, we expected that the material traces would be engraved like patterns resembling those that might be seen on a fashionable product.

Simplifying a Personalization Process

Natural patinas are accumulated smoothly in the trajectory of product usage. Even when users deliberately make material traces on a product, the process is typically short and does not disturb the original product usage. However, since most current personalization systems require several pieces of equipment and software programs for modeling and construction, these systems may disturb users' experiences with the product and make it difficult to personalize products. To embed a personalization system smoothly within the context of product usage, it might be important to simplify the operation process of personalization. For this reason, we conceived a system that covers an entire process from design

to construction. We sought to modify a product quickly and easily by integrating the design and construction parts in a single system. Since the system would be installed in a context in which the product would be used, we had to consider a form factor that harmonized with the product's usage environment.

TRACE-MARKER

To explore the impact and possibility of patina-inspired personalization, we developed Trace-Marker, a laser-based personalization system that supports the accumulation of aesthetic patterns on bicycle bags based on users' riding histories (Figure 1). Based on design considerations, the hardware part was designed for supporting progressive modifications during the product use stage. We also simplified the operation process by integrating the interface for design and the construction part. Regarding software, we digitally recorded bicycling histories and utilized such histories as sources of product personalization.



Figure 1. Trace-Marker

Design Context

To concretize the design considerations regarding and to explore the possibilities of patina-inspired personalization, we developed Trace-Marker to fit the context of bicycling. The first reason we focused on bicycling is that a bicycle and bicycling accessories are now regarded as lifestyle accessories—expressions of an individual. Accordingly, it is common to see heavily customized bicycles with different seats or handle bar designs as examples. Bicycle accessories, such as bags, helmets, and gloves, have become popular among enthusiasts, who often spend more on clothing and fixtures than they do on bicycles. Regarding such customers' needs, we concluded that the bicycling context would be appropriate for applying patina-inspired personalization and studying impacts on symbolic meanings related to personal identity, aesthetics, and social communication. The second reason we focused on bicycling is that many riders frequently use tracking applications, such as Strava [52], MapMyRide [53], and MyTracks [54], that record riding history. These applications all record a GPS-based route, cycling duration, distance, pace, and calories burned. Such digital traces could

work with a patina-inspired personalization system for modifying bicycle accessories.

Considering riders' desire for self-expression and their practice of recording their histories, we tried to develop a personalization system for bicycle accessories, particularly bicycle bags. Inspired by travelers' delight at collecting immigration stamps on their passports or stamps from tourist sites, our personalization system was made to modify a bicycle bag by engraving aesthetic patterns on it.

System Overview & Walkthrough

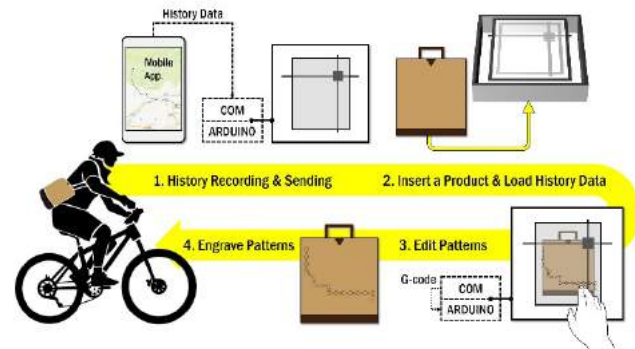


Figure 2. Trace-Marker System Walkthrough

To enable progressive personalization of bicycle accessories based on riding history, users' history data are periodically uploaded from users' mobile phone applications and saved to the local computer for Trace-Marker (Figure 2). To engrave a pattern, a user inserts the bag or other product in the drawer of Trace-Marker. The user logs into the system, which loads his/her riding histories and analyzes them to generate a visual pattern. In the interface, the user edits and places the pattern while looking through the interactive transparent display. Finally, the system engraves the pattern on the product placed in the drawer.

This system is distinct from existing fabrication systems, because it aims to integrate the whole user experience of retrieving history from the tracking application, direct visual editing on a product, and live tracing.

Hardware Implementation

To implement the hardware for Trace-Marker, we considered how to support progressive modification during product usage and how to simplify the personalization process in the context of product use. Thus, the hardware was designed to include three layers of parts (Figure 3): a system interface layer (consisting of a transparent display and a touch panel), a laser plotter, and a drawer. The height of Trace-Marker was set at waist-level (700 mm) so that adult users could control the interface from a standing position. We made the hardware of Trace-Marker similar to other home furniture, aiming for a situation in which this system would be installed in a public space or a home environment.

The bottom part of Trace-Marker was designed as a drawer so that users could engrave on a variety of everyday objects with different heights, such as bicycle bags, caps or mobile

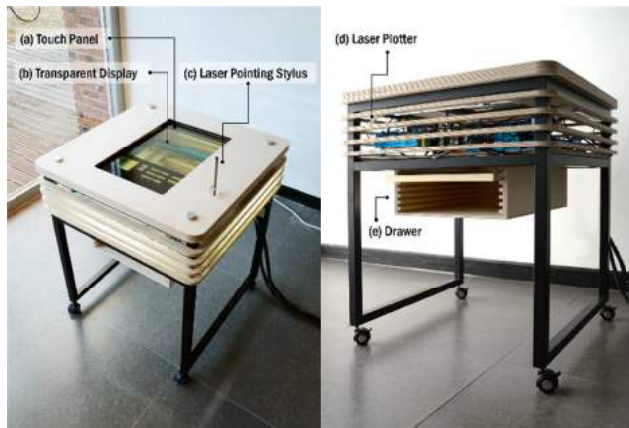


Figure 3. Trace-Marker Hardware: (a) Touch Panel, (b) Transparent Display, (c) Stylus, (d) Laser Plotter, (e) Drawer

phones. To keep a consistent distance from the laser diode, the drawer can be inserted at different heights.

The top of Trace-Marker is made of a transparent display and a touch panel. The see-through interface supports users' progressive designs and the construction process. Users can generate visual patterns for trace engraving while watching modeled patterns displayed above the real product. We added a laser-stylus pen for touch input and to guide the position of the pattern that is to be plotted on the bag.

When a user executes a laser engraving command in the interface, a laser plotter under the interface layer shoots a 405 nm blue-violet laser beam. The maximum work area is about 330 mm by 330 mm, and accuracy is 0.1 mm. The intensity of the laser was adjusted to be safe and suitable for engraving fabrics or leathers. The users were required to wear safety glasses while using the laser.

In addition, we made bicycle bags out of leather. After exploring several materials, we chose natural leather because the engraved lines were more aesthetic than they were for other materials, such as artificial fabrics. The bag's size was made to be suitable for carrying a few bicycle items, such as a water bottle and a wallet.

Software Implementation

While implementing the system's software in the Java environment, we mainly considered how to utilize the digital trace of product use (e.g., bicycling history data) as a source of design so as to transform that digital trace into abstract but aesthetic patterns.

Visual Pattern Design

To generate a visual pattern, we used history data from My Tracks or Strava. These applications generated history data in a format such as GPX (a data format used for GPS navigation devices) or CSV (comma-separated values) that suited our system. Trace-Marker automatically transformed the users' riding histories onto abstract patterns by mapping each data type to predefined pattern-generation templates. The method for generating visual patterns was decided through several phases of exploration.

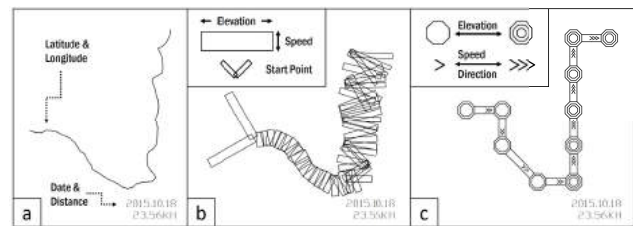


Figure 4. Pattern Styles: (a) Basic Line, (b) Ribbon Style, (c) Metro Style



Figure 5. Examples of Personalized Bags with Ribbon Style and Metro Style

First, we selected (i) the types of riding history data that would be sources for pattern generation. Of the diverse types of riding logs, we chose latitude, longitude, elevation, speed, date, and total distance—the types of information that people generally want to know when using tracking systems. Next, we explored (ii) the overall styles and shapes of the patterns by mapping each set of riding data types onto certain parts of a pattern. Specifically, latitude and longitude were mapped to form a pattern's skeleton. Other types of history data were mapped differently to improve the aesthetics of a pattern style. We also considered (iii) the time required for engraving a pattern. Considering the context of riding, only the vector mode of laser engraving was used; this mode takes a considerably shorter time to engrave than the raster mode does. During our study, the pattern engraving process took roughly between five and twenty minutes. We also evaluated noticeability, the possible number of modifications, and visual aesthetics when deciding on the pattern types.

Finally, the system included two styles of visual patterns (Figures 4 and 5): ribbon and metro. In both styles, latitude and longitude data were used to draw an overall skeleton of a pattern. In the ribbon style, elevation and speed were mapped to the width and height of a rectangle. In the metro style, the overall shape was simplified using nodes and connected lines. As elevation increased, more circles were added at each node. To express the moving speed and direction, arrows were added in the connection lines. Lastly, to provide identity information for the pattern, total distance and date numbers were included in both styles.

Interface

In the interface, five menus were implemented: 1) Load a personal bicycling history, 2) Select a visual style, 3) Edit a pattern, 4) Transform (Change a pattern's position and size), and 5) Engrave (Figure 6).

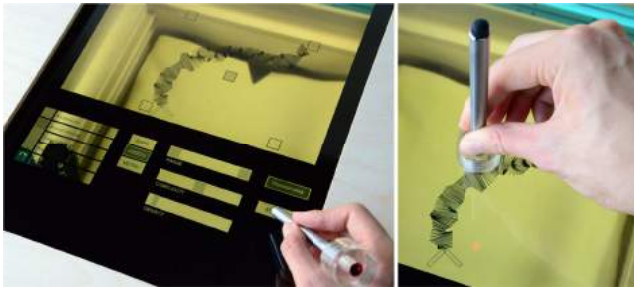


Figure 6. Interface: Selecting Menus (Left), Estimating the Position of Patterns with the Laser Pointing Stylus (Right)

To start personalization, users selected and loaded their bicycling histories. Then, the GPS route from the data was drawn on the display. Users selected a visual style based on the GPS route and other history data. In the Edit menu, users cropped the route and adjusted the complexity and density of the pattern. Size and position buttons allowed users to change the size and position of a pattern. This was done while viewing the pattern on the bag through the transparent display. The laser pointing stylus could be used to check the plotting position of a pattern on the bag. When the engraving process was executed, the system sent G-codes to the laser plotter, which was controlled by an Arduino board. According to the user-defined pattern, the plotter controlled the stepper motors and the laser diode.

FIELD TRIAL

We conducted a field study to understand not only the usability of the patina-inspired personalization system but also the impacts of the system on users' experiences. Specifically, we expected to determine how patina-inspired personalization would be embedded in the context of product use. We also wanted to find out how patina-inspired personalization could be used for attaching participants' personal meanings to the personalized products.

For that, we expected that users would need a certain amount of time to become accustomed to using the Trace-Marker system. Thus, we had 10 participants use Trace-Marker for three weeks. The sample size and the length of the field trial were determined from a previous study [4] that discussed field trial methods. Given the exploratory nature of our design work, we focused on gathering a rich set of opinions (rather than on quantitative findings) and aimed to encourage reflective thinking about the personalization approach and personalized products.

Participants

We recruited 10 participants (6 male and 4 female, ages ranging from 19 to 29 years, $M = 25.1$, $SD = 3.4$) who rode a bicycle regularly and who were interested in DIY culture. Their past experiences in tracking their bicycling were also

considered in the recruitment phase. To reduce the novelty of activity logging itself, only people who had previous experience recording some sort of physical activity using mobile applications (e.g., Strava, or MyTracks) or other relevant devices (e.g., Garmin Edge [55]) were selected. Throughout the paper we refer to each participant using gender and the week of the interview session (e.g., M5, week 3). All participants periodically rode a bicycle for exercise, as a hobby or to commute. Five of the participants partook in bicycle clubs and rode for long distances every week (more than 100 kilometers): M1, M2, M3, M6, and F3. In addition, four participants (M2, M5, M6, and F3) had experience customizing their bicycles.

Method



Figure 7. Example Participant (M3) & Personalization Task

During the field trial, one preliminary interview session and three main sessions—including an interview and a personalization process—were conducted. To minimize the participants' burden, Trace-Marker was installed in a building that participants could reach within 10 minutes by foot (Figure 7). The interview sessions were conducted right after using the system.

The preliminary interview session included questions related to the participants' biographies, their normal practices while riding a bicycle, and their views of activity tracking. In this session, we provided a bicycle bag and asked participants to check on or set up their cycling applications. We explained how to export their riding history data periodically to the local computer for use with Trace-Marker.

Once per week for three weeks, the participants visited us to use Trace-Marker and to have an hour-long interview session. Before each interview, they could engrave one or two patterns. During each interview, we asked questions about the impact that the patina-inspired personalization had on their experiences and the functional, emotional, and symbolic aspects of Trace-Marker and the modified bags. Additionally, in the 3rd week, we also asked about the possibility of applying patina-inspired personalization in diverse products and service contexts after conducting a design workshop with the participants.

Data Collection and Analysis Method

We analyzed the results based on observations of participants' use of the system and on the weekly interviews. The weekly photos of participants' bicycle bags and their riding histories were used to identify the detailed situations that the users mentioned in their interviews. A total of 20 hours of interviews were audio-recorded and transcribed. Our research team categorized the data from the interview

transcriptions and contextual data, including bicycling data and photos of the participants' bags, through iterative analytic induction. During the analysis, we considered novelty effects and tried to find unexpected uses [4].

FINDINGS

The participants positively received the idea of personalizing bicycle bags using their bicycling histories. Though most participants were concerned that they would need professional design knowledge before using the system, all participants were able to easily select history data, edit a visual pattern, and place the pattern as they wanted, even in the 1st week. Three participants (M2, M6, and F3) who had previous experience using professional fabrication systems mentioned that the Trace-Marker was less costly and burdensome than the existing fabrication systems which require separate design software and fabrication equipment. Participants noted that the interface in which they could design patterns above real bags was useful to predict the outcome so that they could be assured of their designs: *"Unlike existing fabrication systems, this system supports design right over real objects, so I could feel confident of my design decision"* (M2, week 2). In addition, participants enjoyed watching the process of personalization. Overall, the process of designing a pattern for a bag took less than five minutes. Depending on the size and density of the pattern, engraving took five to twenty minutes. Due to the irregular surface height of the bags, the patterns were engraved with different degrees of vividness.

In the following section, we explain how Trace-Marker was used for personalizing bicycle bags over three weeks and how the system was embedded in the context of bicycle riders while attaching personal meanings to the bicycle bags.

Progressive Personalization for Expressing Personal Stories and Identities

During the field study, we observed that participants' bicycle bags became varied after three to five uses of the system (Figure 8). According to participants' riding histories and aesthetic preferences, all participants' bags became visually distinguishable by the last week. We found out that from the 1st personalization, participants established criteria about what kinds of patterns would be accumulated and how they

would place patterns on the bag. Through the process of accumulating patterns, participants could gradually add personal stories and identities about bicycling to their bags.

Engraving a Pattern like Keeping a Diary

It was common for our participants to select history data that represented their daily cycling lifestyle. For example, M4 and F2, who ride bicycles for transportation, mentioned that they selected histories that were related to their frequently visited commuting routes: *"I want to use this system like a diary, so I engraved with the history that shows my commute from my home to my office or from my home to frequently visited markets etc."* (M4, week 2). Sometimes, participants chose a history that recorded an unexpected or unusual event. *"One day, I fell off my bicycle and chafed my knee, and visited a hospital. This pattern exactly shows the story. This crumpled part is when I got injured"* (M2, week 1).

During the participants' three to five times using Trace-Marker, some tried to build a single big pattern that showed a personally meaningful story by combining individual patterns. They arranged each pattern like the pieces of a puzzle. For example, F2 tried to place patterns related to a frequently visited location, making a map over her bag: *"I wanted to complete a map that shows my daily routine with my bicycle. At the center of my bag, I placed this pattern that shows the way from my home to my office, and the right pattern is the way to my favorite restaurant"* (F2, week 3). In this way, she tried to modify her bag to represent her life.

Engraving a Pattern to Show Off

Some participants (M1, M2, M3, M5, and M6) who ride mainly as a hobby or exercise activity selected histories that represented challenges and accomplishments. Thus, they tried to engrave patterns that showed how fast and how far they had ridden or how high they had climbed: *"I rode a mountain bike last week, which was really tough. I wanted to engrave this ribbon pattern since it shows the elevation clearly"* (M5, week 1), *"This week I tried to ride at the speed of 30 kilometers per hour, which is difficult for amateur riders. This history is chosen to show off my progress"* (M6, week 1). Throughout several pattern engravings, the participants tried to make bags that represented their identities as avid cyclists: *"This week, I rode much farther*



Figure 8. Participants' Bicycle Bags after 3 - 5 Times of Pattern Engraving

than usual, so I placed this pattern above the pattern based on my usual riding. Like this, this bag will show how hard I ride” (M5, week 2). The participants mentioned that their bags’ patterns felt like rewards.

Likewise, we found that most participants tried to place each pattern so that the accumulated patterns would represent their bicycling experience and symbolize their identities and lifestyles. At the same time, because the patterns might be shown to others, participants considered aesthetics and harmony with the patterns previously engraved on the bag.

Embracing Personalization as Part of Product Experience

We investigated whether Trace-Marker was smoothly embedded in the context of bicycle riders. During the study, we found that the system led participants reflect on their past experience and even affected their bicycling habits.

Stimulating Reflection on Past Experiences

In general, participants became curious about the patterns and tried to associate the patinas with their past experiences after engraving a new pattern. Participants mentioned that the mobile application was suitable for checking the accuracy of numerical values, such as average speed or calories burned. On the other hand, the abstract aspect of the patina-like patterns caused participants to interpret and question the shape of the patterns and their past experiences: “(While looking at the engraved pattern) I think this part shows when I climbed up the hill. That’s why the ribbon is getting wider” (M5, week 1). In this way, we observed that Trace-Marker stimulated reflection and enabled past experiences to be seen from unusual perspectives.

Influencing on Users’ Behaviors

Trace-Marker was developed to progressively modify bicycle bags based on past histories of bicycling. While we expected that only past bicycle usage would influence the personalization of the bags, we observed that the system also influenced how the participants used their bicycles.

First, participants tried to record riding histories regularly because they wanted to accumulate patterns that showed their general lives or special events. For instance, F4 was concerned that if she did not record her history constantly, the patina pattern would be irrelevant to her general lifestyle: “Usually I do not use tracking applications, but I tried to record my riding experience regularly because it is better to make patterns which correspond to me” (F4, week 2). Moreover, participants were motivated to take a different route or to increase the frequency of cycling to engrave more diverse and more aesthetic patterns on the bags: “Usually I take a linear route from home to the park, but this week I rode in a circular route for making a circular and aesthetic pattern” (M1, week 2); “Since a bicycle is just transportation for me, I do not usually go to special places, but, to make diverse shapes of patterns, I went home another way” (F1, week 3). In this way, participants embraced the personalization process as a part of their bicycling and even changed their ways of riding.

Strengthening the Emotional Bond with Products

Distinct from other fabrication research, which mainly reports excitement regarding custom products, our study revealed the impact of patina-inspired personalization on emotional bonds with products. Though participants first felt interests in using the personalization process itself, their initial interest faded after the 1st week. Nevertheless, their emotional bonds with their bags and patterns were strengthened in the following weeks. Comparing the participants’ perceptions of the bicycle bag during the first week and the last week (after modifying the bag several times), we observed that their emotional bonds with the bags became stronger: “Though other participants’ bags may look nicer, I will prefer my bag. It is like a part of me.” (M3, week 3). During the interviews, participants described two reasons for forming such emotional bonds.

Users’ Involvement in Personalizing a Product

Participants said that their involvement in the design process made their bicycle bags more meaningful. They felt engaged in the process of selecting histories and personalizing their bags with new patterns: “Even if I assemble IKEA furniture, it will end up with just like others’ furniture. Though I do not make a product, this system supports my design, which leads to more unique products” (M4, week 3).

Involvement in making a product gives a person a greater stake in it and a deeper connection with it [21]. In our study, though the main function of Trace-Marker was not to create a new product, participants felt as if they were directly involved in creating one-of-a-kind products because the planning a pattern and modifying a bag required effort and personal decisions: “If I build my house, I will just make a blueprint about my house rather than piling up bricks. This system is close to making a blueprint of a product. Making all parts of a product costs too much.” (M3, week 3).

Formation of Memories Anchored in a Product Itself

Furthermore, most participants felt that the uniqueness of each bag was enhanced by the fact that the accumulated patterns were based on their past experiences: “Rather than just selecting predefined patterns, these patterns are generated from my one of a kind experience. It would be impossible to generate the same patterns” (M4, week 3). In addition to this uniqueness, during the last week of the field study, participants said that their bags reminded them of their lives or their efforts in bicycling. They liked that material traces in the bag would last longer than the digital traces from mobile applications. They also mentioned that the permanently engraved patterns, similar to natural patinas, enhanced the historical value of their bags: “Since the patterns on my bag had changed along with my experiences, it feels like a growth ring” (F1, week 2).

According to Belk’s concept of the *extended self*, external objects may be viewed as part of oneself, when the objects serve as reminders and confirmers of one’s identity [2]. Because the bag could become a convenient means of viewing oneself, it could have a strong symbolic meaning

that would not be replaced by other bags. In general, product-related memories develop independently from a product's design and manufacture and are thus difficult for designers to influence [29]. However, in this study we observed the possibility of patina-inspired personalization for embedding users' memories about their meaningful experience into a product.

DISCUSSION

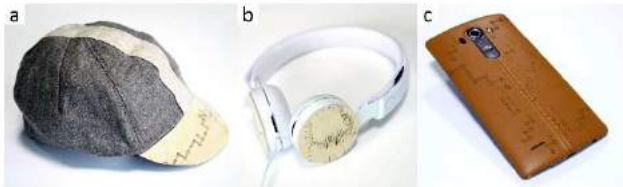


Figure 9. Using Patina-inspired Personalization for Other Products: (a) Cycling Hat, (b) Headphones, (c) Smart Phone

In our study, we found that product personalization based on history of bicycle journey helped participants to add personal stories and identities to their bags. Participants embraced the personalization process as part of their product use. This result implies that patina-inspired personalization has potential as alternative design approach for enhancing the symbolic meanings of a product as a self-expressive possession. We think that the patina-inspired personalization would also be beneficial and applicable to IT products and services. Though we used a mobile application for recording users' digital traces, today, many physical products are being used together with integrated product-service systems (e.g., Nike+ & Fuel Band); or they can also independently collect, process, and produce information about users' experiences. At the same time, their aesthetic and symbolic qualities as fashion items are essential. Accordingly, it would be possible to detect memorable events while using product-service systems to improve products' aesthetic and meaningful aspects.

In the following, we discuss how patina-inspired personalization can be applied in wider contexts and domains. In the design workshop conducted during the last week of the field study, we asked participants to select one of their possessions and to design a pattern on that possession by mapping history-related data, as Trace-Marker did. Though Trace-Marker was applied for modifying bicycle bags, participants desired to use the system on their bicycles and other items such as a cycling cap, a smart phone, a skateboard, shoes or a pair of headphones (Figure 9). Combining the results of field study and the design workshop, we discuss implications to improve the use of patina-inspired personalization.

Design Implications for Patina-inspired Personalization

Tailoring Digital Traces for Enhancing Symbolic Meanings

The patina-inspired personalization utilizes digital traces from users' product-related experiences to make material traces arranged like a pattern. To enhance the symbolic meaning about the users, it is important to consider the

association among the type of digital traces and the users' experiences with their products. For instance, M1 mentioned that for headphones, history data about a frequently played song or a favorite genre or artist would be proper for making patterns. M6 said that he wanted to modify skateboards based on history data related to his skill progress: "When I ride my skateboard, the location or speed is not important. I want to accumulate patterns that show the techniques that I perform, such as flips, jumps and the level of tricks" (M6, week 3). In this way, it is necessary for designers to select proper types of digital traces and tailor them to symbolize users' unique and important experiences with the products. It would also be possible to help users freely select and edit digital traces to highlight some of their histories.

Balancing Automation and User Involvement

As participants became adapted to our system during three weeks, they expressed different desires about the system's automation and user involvement. For example, M5 and F1, who had little experience in design, mentioned that they hesitated to execute engravings because of uncertainty about their knowledge of aesthetics. On the other hand, M6 and F3, who had more experience in designing and DIY practices, expressed a desire for detailed involvement. They wanted to change the shape of the patterns and map certain data to a specific part of a pattern.

In general, commercial product personalization services allow people to create a product by selecting components from a predefined set of options. Norman said that these services are better at making personalization easy, but they do not directly guarantee emotional bonding [33]. That is mainly because the services require little physical or mental effort. Meanwhile, more effortful product personalization might have a downside as well. As the effort invested increases, so does the perceived complexity of the task and, consequently, the possibility that people become confused [7].

Therefore, users with different levels of proficiency could be offered separate interfaces in patina-inspired personalization. For novice users, the system could automatically generate a pattern and place it according to predefined templates. It might also provide examples or recommendations about how the patterns could be aesthetically placed. For more experienced users, a parameter-based interface [34] could allow them to directly define and modify details of the patterns and the modification mechanism. With a high level of involvement, these users might be able to make more personalized products that could become clear memory cues.

Permanent or Erasable Traces

Our personalization system uses a laser diode to make unmodifiable material traces. In contrast to digital traces in mobile applications, the permanently engraved traces improved the historical value of the participants' bags. However, in the current system, one concern is the limited number of possible engravings that can be made on the surface of a given product. When we asked about a situation in which the bag would be full of patterns, most participants

said that they would want to replace the front cover of the bag with a new cover and keep the old one to serve as a gift or a souvenir.

As an alternative solution, we expect that it will be possible to increase the dimensions of a pattern expression by applying additive or subtractive fabrication mechanisms. Though Trace-Marker generated single-colored patterns, if gradations and variations of color become possible in the system, more patterns could be accumulated, allowing overlapped patterns to maintain their own expressions. Erasable materials could also be applied to the patina-inspired personalization for long-term use and to protect against design mistakes, as was tried with the Shader Printer [41]. In addition to the problem of the limited number of engravings, participants mentioned their discomfort when making design mistakes. During design and construction activities, it is common to experience trial and error. Thus, though the interface of Trace-Marker helped to predict how the fabrication would look, erasable materials might help the users of patina-inspired personalization systems. Since there permanent and erasable traces might have different values, the mechanisms of patina-inspired personalization should be selected based on users' needs and the context of the product's use.

Technical Improvements

Calibrating Personalization Mechanism

To support the progressive personalization of diverse products including 3D objects, the patina-inspired personalization system could be developed to detect the dimensions and materials of a product. During the field trial, we found that the forms of the participants' bicycle bags changed through long-term usage; this inconsistency caused different engraving effects. The intensity of the laser diode also had to be adjusted according to the varying solidity of product materials. Thus, 3D scanning technology or other visual sensing technologies would be helpful to self-calibrate the fabrication mechanism after detecting the current status of the inserted products [11,40,44].

Improving a Parallax in the Interface Layer

In the current system, we used a transparent display and touch panel to simplify the design and construction processes. The advantage of such an interface was that participants could predict the outcome before executing construction of the product, thus creating certainty about the decision. However, the space between the image on the transparent display and the actual product (which was 200 mm) created a parallax and sometimes caused inaccurate engraving. Though participants moved their head to watch the interface and the bag vertically, their view from above the display did not match perfectly with the position of the bag. For this reason, participants had difficulty placing patterns in the desired positions. To solve this problem, it might be possible to automatically adjust the position of the patterns in the display by detecting the angle between users' eyes and the position

of the products. Users might then be able to implement a more accurate design on the product.

Limitations and Future Work

In this research project, we conducted a field study for three weeks in a specific product context. As the system used a laser, it could not be installed freely in public due to safety issues. A longer "in the wild" study may show other impacts of patina-inspired personalization [4]. First, in such studies, it will be possible to investigate if personalization leads to long-term effects related to product attachment or emotional durability [5,12,29]. Although we studied the impacts on a symbolic meaning of a product, the symbolic meaning seems to be a particularly important factor influencing users' emotions and product attachment. Desmet argued that it may be more fruitful to establish a long-term emotional relationship between a product and a consumer after a purchase situation [9]. In this respect, it will be beneficial to study whether patina-inspired personalization may enable a continued close relationship between a product and a user over an extended period of time. Though we observed that participants felt close to their products during the field study, a longer study would be helpful to investigate other issues, such as whether the users postpone disposal of products and how patina-endowed objects may be valued beyond the first owner. Second, an "in the wild" study setting may be helpful to observe which other product contexts are applicable and how the system can be used to create patinas for events other than bicycling.

CONCLUSION

Our motivation for conducting this study was to suggest product personalization in a way that enriches a symbolic meaning of a product as a self-expressive means. Thus, in this paper, we presented the concept of patina-inspired personalization through accumulated traces of product use. Based on an understanding of how patinas' characteristics add value to objects, we derived the design considerations for patina-inspired personalization related to the timing, source, expression, and personalization process. Then, we developed Trace-Marker, which was specialized in the bicycling context, to investigate the impacts of patina-inspired personalization.

With the deployment of this system, we found that the process of accumulating patina-like traces helped participants add personal stories and identities to their bags. Also, the use of Trace-Marker stimulated reflection and enabled past experiences to be seen from unusual perspectives. Participants' emotional bonds with the bags also became stronger. We expect this research to inspire diverse product personalization services and general fashion and product designs.

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