Data-Objects: Re-Designing Everyday Objects as Tactile Affective Interfaces

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Abstract— Data-Objects **introduces the idea of re-designing physical objects that a person uses every day to act as tactile affective interfaces.** ***Data-Objects*** **are a means to provide users information about their use of different everyday objects and how it affects them. We do this by re-designing the objects to embed information in the physical body of the object itself without hampering its original functional capability. By 3D printing the body in a set period of time, differences in the information represented on the physical body over the time are aimed at highlighting patterns of how the usage of that object has been affecting the user. The overwhelming digital information that we are exposed to and the disconnect that it has from what it is representing makes the relation of the information to the different aspects of our life not effective. We think that using physical forms of objects to provide information can make the data more meaningful, enhancing the value of the object beyond its intended function. Physical forms can provide subliminal and tactile feedback to the users as they use the objects throughout the day, without specific visual attention. Being present physically ensures that people are more conscious of the data and patterns, and makes the data visible to other people as well.**

Keywords— Material data representation; 3D printing; Tactile feedback

I. Introduction

There are many daily objects and devices that people use without being cognizant of how the activity associated with that object is affecting them. We propose a novel way in which people can be made more aware of the effect of use of a particular object. We do this by mapping the information of usage effect of an object on the physical form of the object itself, thereby adding another layer of personalization, meaning and function.

In recent years, we have witnessed the advent of 3D printing technology, its declining costs and its easy accessibility to the masses [1]. There have also been rapid advancements in sensing and data logging technology resulting in a growing interest in using sensor technology to foster lifestyle changes in people, especially in the health domain [2][3][18]. We see a tremendous opportunity in combining these two emerging technologies to create meaningful and contextually relevant means of physical information representation.

Khot et al. observed that material artifacts based on physical activity make participants more conscious about their involvement in physical activity [4]. We further believe that physical objects representing contextually relevant information about the effect associated with a particular object itself, will over time, serve the purpose of acting like physical diaries, and playing significant role in making one mindful of patterns of effect of objects in our daily lives. This is especially true for various types of data, whose analysis makes sense over a long period of time, rather than instantly [5], for example health affective data while using a device. Also, physical objects often exist in public space, and are readily seen by people around, as opposed to digital data, which often is not. This, as observed by Vande Moere [6], will increase the likelihood of these objects acting as incentives to make people reflect and act upon their data patterns. Therefore, through *Data-Objects*, we aim to add more meaning and personalization to everyday objects that we use during a day, without being aware of the effect of the related activity on us.

A. Related work

1) Towards Physicalizing data

There exist a number of ways to represent information today, but most of them are digital in medium. On the one hand, the virtual medium is beneficial for data visualization as it has interactive capabilities (such as allowing for zooming into data), and support for dynamic updates of the data. On the other hand, the virtual representation has some limitations as to what can be experienced with it, as argued by Vande More [6] and Victor [7]. For example, the virtual and visual medium requires a flat display surface that is less perceivable in daylight and demands high visual attention without which one cannot parse the data [8].

Vande Moere [6] argues that a material representation carries a meaning beyond the data itself as it “can be touched, explored, carried, and even processed”, thus potentially encouraging people to reflect on their behavior yielding more engaging and educational experiences. A study by Jansen et al. [9] compared virtual and material visualizations of physical data, and found that visualizations of data in material form can be easier to understand for the user because of its 3D features.

**Both authors contributed equally to this work*

In addition to the difficulties of 2D representation, we believe there is a major disconnect between the medium of information representation and what the information is being represented about, often requiring users to connect that gap themselves. For example, representing information about the consumption of coffee on a tablet has an inherent disconnect in the source and medium of representation and how the two activities are experienced – one through the coffee cup and the other through a flat screen.

Despite physical forms of data representation have been tried in the past, with examples such as [5][8][9], there is still a disconnect between what the information is about and where people see it. There is no contextual or functional relevance to the 3D object when the physical artifact of data remains a standalone place with no other functional purpose. Our user study, discussed later, points out that this contextual, in-time information acts as a trigger to help user be aware of how the object's usage effects them while they use the object throughout the day.

Through *Data-Objects*, we create a means for providing information about an object's effect on a user by physically embedding such information on that object itself. We believe that our approach of representing information through the object's physical body will offer in-time tactile cues to the users as they utilize the object at various times of the day. This is opposed to separate stand-alone artifacts where the materiality does not play a major role, as the user does not often interact with the object physically. As Fogg's behavior model points out, a trigger is needed to cause an action [10]. The Fogg Behavior Model shows that three elements must converge at the same moment for a behavior to occur: motivation, ability, and trigger. Various ways of representing health data are a means of providing a trigger to the user to act. However, with digital or stand-alone physical data representations, the relevant data is not presented to the user while using they carry out an action, thereby not providing effective triggers. Data-objects approaches to change that by providing contextually relevant tactile cues to the user. As highlighted in Fig. 1, Data-Objects is aimed to create a new research space of contextually relevant physical objects as a means of data representation. By highlighting the prior work, we show how this is a new area of work.

2) Affective persuasive data

The data that we perceive can be communicated affectively by means of computer work. For instance, Swan [11] described the past and future of the quantified self (QS) movement, stating that it will evolve from data representing physical information, to data that represents qualitative knowledge, such as emotions, leading to loops for behavior change.

Kocielnik et al. [12] proposed LifelogExplorer as a tool to generate views of stress data from a person, in order to make it easier and accessible to understand personal information that is not usually perceivable. Similarly, McDuff et al. [14] described AffectAura, a tool that saves user's valence, arousal, and engagement correlated with external information that is utilized for users to reflect upon. All these tools discuss various ways of capturing information and representing it digitally.

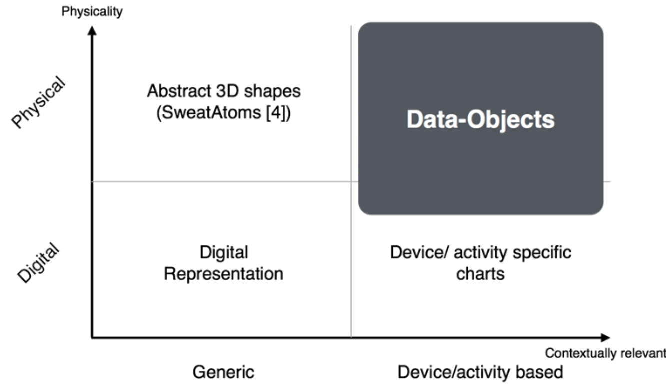

Fig. 1 New research space that Data-Objects is covering.

Different data structures represented in textures and forms can elicit different emotion to a person. Tsalamlal et al. [13] analyzed, through a user-study, the relationships between the physical features of an air jet, which simulates tactile sensations, and the perception of emotions by participants through the variation in valence, arousal, and dominance. This research points to how tactile input can be a great means to represent feelings of emotion.

These works proposed how methods of transmitting data, can infer more personal and meaningful information to the users. *Data-Objects* aims to creating physical data to embody personal information making the objects we use daily more affective.

II. DATA-OBJECTS

Data-Objects employs personal physiological data of the user that is affected by tasks and activities we perform daily through diverse set of quotidian objects. In the following sections, we discuss the design of the Data-Objects, by describing the data-sets used, the thoughts behind designing the objects and the way we fabricate them.

A. Datasets

The affective and physical state of a person can be determined by analyzing different physiological parameters [15]. With the current advancements in commercial wearable devices, such as smart-watches or wristbands that track physical and physiological data of our body, it is being feasible to understand a person's activity throughout the day.

In the current implementation of *Data-Objects*, we use Heart Rate (HR) as the primary source of dataset that we embed in the physical form of the objects. We differentiate the HR in different scenarios, making it an indicator of the physiological effect of use of different objects or activities associated with different situations and objects.

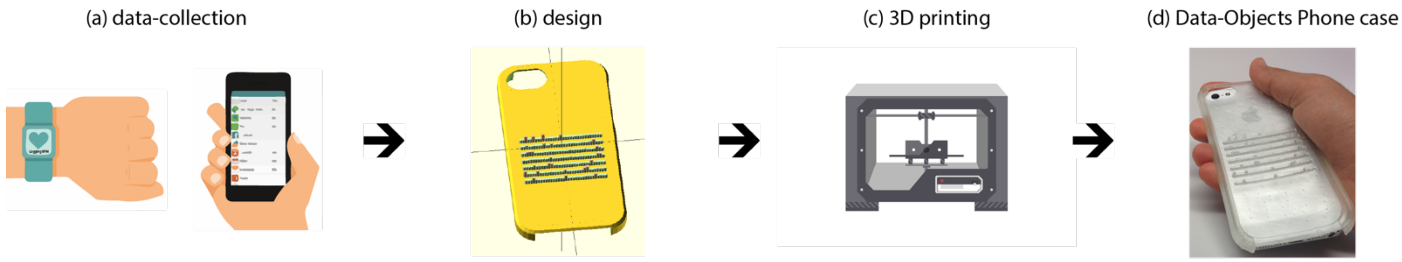

Fig. 2. Workflow of Data-Objects.

To collect the heart rate – in beats per minute (BPM) – we use a smart-watch, concretely the model Moto 360, which has a built-in heart rate monitor. By developing a custom application installed in this device, we collect the wearer's HR in periods of 3 minutes in order to get an insight of the variation during the day.

The heart rate differs in different activities or in using different tools and objects. For this reason, to be able to discern them, the user selects the object s/he is using. We also use a usage logging application on a computer and phone to map the BPM data to phone or computer activity. For mapping BPM data to coffee, we ask the user to make notes personally and take that information.

In order to explore more detailed inner state of the person, more data can be combined, such as respiration rate and electrodermal activity, as they are directly related to the emotional state of a person.

B. *Design of Objects*

Objects can provide different sensations through their difference in shape, temperature, friction or stiffness. However, in the current state of the art, objects do not react to the changes in the user's physiological, and ultimately, emotional state. Through *Data-Objects* we add layers of personal data in form of physical properties that is perceived by the user subtlety, without hampering the usability of the object itself. We present three types of objects that are directly related to our everyday work and, hence, to our inner state: phone, mouse, and coffee mug.

As the shape of these three different types of objects differs, the design characteristics for each one is considered. By having the heart rate dataset that each object elicits throughout the day, we opted to change the shape of the object so that they can be perceived as continuous in time.

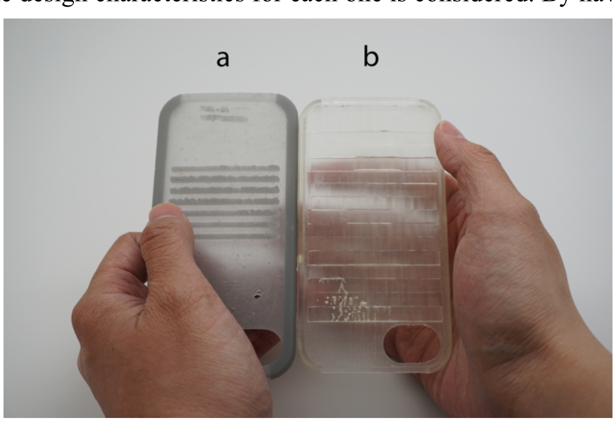

Fig. 3. Different versions of the Data-Objects phone case: (a) discontinuous, and (b) continuous.

The design of each object was parameterized considering the shape of the objects, and also analyzing the data representing the user's heart rate. We utilized the program OpenSCAD, an open-source software application for creating 3D CAD models.

1) Phone Casae

In recent years, there is an increasing amount of people who use mobile phones, spend a large amount of time on it daily. To provide information of how phone usage is affecting a person, we map the BPM values while a person uses a phone on *top of a generalized phone case shape.*

During the process of designing the prototype of the phone case, we created different models that could represent the heart-rate data (see Fig. 3). We tried both a continuous changing model and a more spike-oriented model. After fabricating the two and trying it out, we realized that the smoother, continuous one, though more pleasant to look at, was tough to get information from. We went ahead with the spiked version with all the objects.

We plotted the data we collected by transforming the shape of its flat area. Taking the time period of one week, we formed seven horizontal "lines", each one representing one specific day. Through the variation of height, different tactile sensations are perceived in form of change in roughness. In the design for BPM data, the continuous flat data represents the average BPM level

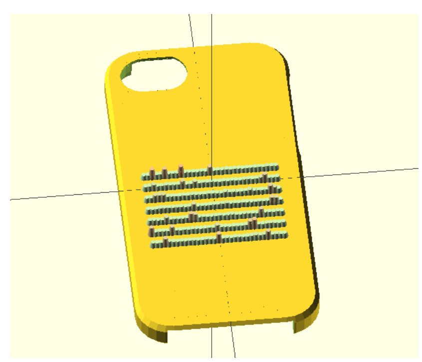

Fig. 4. Colored phone case model.

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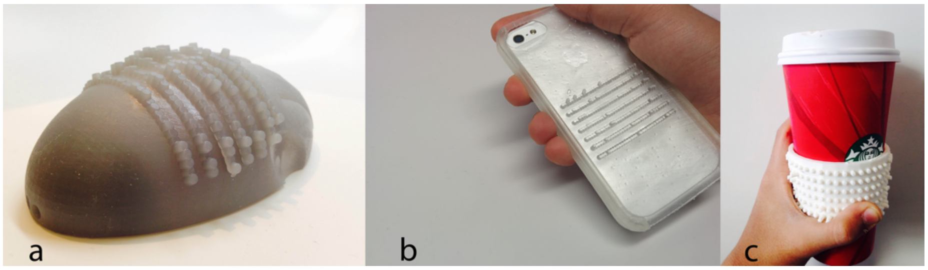


Fig. 5. Data-Objects design models: (a) mouse cover, (b) phone case, and (c) coffee mug sleeve.

of the user to give him/her a clear indication of relative rise or fall while using the phone and at what time of the day that would happen. In the design, we placed the data where the user can perceive the tactile cues while using the phone, without altering negatively its usability and being uncomfortable to carry. The data points are modeled as flat-headed spikes so as to make them easy to interpret and to provide good tactile information. Furthermore, another layer of representation to the phone case model was added, being represented as color change to give visual cues to the user, instead of a single variation in shape (see Fig. 4).

2) *Coffe Cup Sleeve*

The second type of object we use is the coffee mug, or similarly the coffee cup sleeve that has effect, both positive and negative as it is directly related to coffee or tea consuming [16][17]. Thorough the day, we may have use of it usually in specific times of day.

We modified a coffee cup sleeve that can be used for a standard commercial coffee cup (see Fig 5.c). The values of the heart rate data were mapped before, during, and after the use of the cup, to a 3D design of the sleeve representing the data, in a similar manner as done for the phone case. The design represents seven days of a week with each circular ring representing a day, this way, the holder can perceive the data of a whole set of time period while still having its functionality unaltered The data spikes cover 2/3rd of the circular section of the sleeve, and the remaining 1/3rd is left blank. This makes the data be noticed under the palm and under the fingers, making it easy to get tactile feedback through change in shape.

3) *Mouse*

The third element that rises interest to conceive personal data is one that is related to both productivity and entertainment in an era that is focused on the digital world. The mouse is used to represent the variations in physiological signals while in front of the computer using applications, either for entertainment or productivity. We created a prototype of a casing for a mouse, with the objective of giving feedback to the user of the effects in the use of it.

The design, similarly as the cases aforementioned, represents data of a specific time period, one week for instance, with each horizontal line representing data for one day. The part of the mouse where the palm makes the main contact with the body was chosen as the area to represent data (see Fig 5.a).

C. *Transforming to physical*

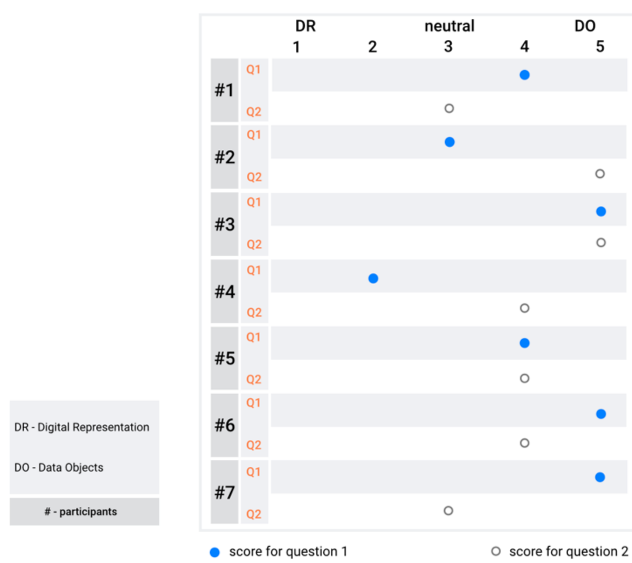
With the designs created digitally with the data from the person, they were crafted using a 3D printer (Formlabs Form 1+ Desktop printer).

III. User Study

We conducted a preliminary user study with 7 participants (3 female, and 4 male) with average age 23.7. The hypothesis we wanted to test was if contextually relevant tactile information representation is better for users to understand information about effect of use of a particular object, as opposed to non-contextually relevant digital representation. We designed a user study where we fabricated Data-Objects' phone case covers, coffee sleeves and mouse covers (DO) for participants based on the system described above and gave these to the users for a week to use. We also provided them a digital representation (DR) of the same data, which they could access at any time of the week. This DR serves as a basis to compare the effectiveness of dynamic, both in shape and time, of the digital information to the users.

The experiment had a set time period, duration of which was seven days, in which the participants were using the objects and data we provided. In the conclusion of the experiment, they were asked to rate on a scale of 1 to 5 the following attributes of DO and DR:

Table I. Results from the User Study



1) Ease of accessing the information at various times of the day.

2) Ease of connecting the information accessed with activity and objects associated.

The quantitative results for the seven participants are shown in Table I. The average score for the first question was 3.7 inclined towards DO and for the second was 4.2 inclined towards DO as well.

In addition to the quantitative data, qualitative feedback from the participants was collected as well. The results of our study supported the initial belief that there is an increase of ease of access and understand by employing tactile information as compared to solely visual representation in digital format. It also supported our hypothesis that providing data of an object on its physical body is beneficial for people to relate the information with an activity that is executed with the particular object or objects.

The qualitative statements gave us insights about the benefits and drawbacks of our system. A participant raised a valid point of having to preserve the various data-objects products over weeks to be able to analyze patterns emerging from them. Another participant said, "I could figure out information by just feeling it, and not consciously looking at it, allowing me to access information without giving constant thought. Other participant stated, "If I could also have tactile real-time information update on the Data-Objects, it will be very nice." This last comment highlights one of the drawbacks of the Data-Objects system where-in real-time information is not available. While Data-Objects serves the purpose of a physical diary very well, it does not support dynamic update of information.

IV. Conclusions and Future Work

This paper discusses a new approach of embedding information related to, and emerging from the use of everyday objects in the physical body of those objects themselves, making the objects more personal and meaningful. We present this idea with an aim of reducing the gap between the medium of representation of information and the source of that information. To put forth the concept, we implemented designs of three objects that a person uses everyday to carry out various activities using BPM values while a person uses those particular objects. We tested our hypothesis that contextually relevant tactile information representation is better for users to understand information about effect of use of object as opposed to non-contextually relevant digital representation through a preliminary user study and found positive results.

We aim to work on the design of the *Data-Objects* to take the idea forward. Exploration will continue of the aesthetic design of the objects we create, and work on better designs to represent information. Our two-pronged goal in creating the designs is to ensure that the information is easily perceptible to the user, both visually and through tactile feedback, and the functionality of the object is in no way compromised. Therefore, the direction we want to push it in is to make the designs such that they do not entirely look like data plots, but at the same time are not too abstract so as to not achieve the purpose of letting people understand and reflect upon their data easily. Furthermore, we will also work to identify more objects of daily use, and the data sets relevant to those objects, might be even more than one set in an object, which we could embed in them in their physical form.

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