Data City: Leveraging Data Embodiment Towards Building the Sense of Data Ownership

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Abstract. Human-Data Interaction (HDI) is an emerging area of research as personal data are being increasingly collected, analyzed and traded. We conducted a small-scale qualitative research to explore people's perception, behaviour and attitude towards data via survey, interview and workshop. The results revealed that the vagueness of data ownership is the main concern. To form a better understanding, also help the novice users to have an enhanced awareness on their data privacy, together with the findings, we leverage embodied interaction aiming at enhancing the sense of data ownership through providing augmented physical representations. Following this approach, we propose an Augmented Reality installation 'DataCity' as a sample application, that connects the user's smartphone application data to physical objects. Through physical manipulation and augmented reality control, our design provides evidence on how to clear the boundaries of users' personal data, building their senses of ownership and eventually develop a better privacy literacy.

Keywords: Data embodiment · Data ownership · Human-Data Interaction

1 Introduction

We are living in an era in which ubiquitous computing via mobile and IoT device is emerging, and normal and novice users are yet to have a sufficient understanding of the digital information generated by them [12].

With the development of Big Data technology, personal data, as one of the richest class of data [20], becomes extremely valuable, in particular in targeted advertising, because of its capability in performing users' behavior profiling [22]. Yet from the users' point of view, such information may be considered private and sensitive [9]. Over the years, researchers, regulatory bodies and activists have articulated the power imbalance in personal data between individuals and third-party entities that collect, analyze and distribute their data [5, 22, 27]. Regular users must gain awareness for their data and develop better privacy literacy [23].

However, according to recent studies, users normally have a complex attitude towards the privacy issues of their data, and sometimes contradictory [24]. When asked explicitly about their attitudes on privacy, users generally show a high awareness towards their data

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privacy, but it does not reflect on their daily behavior [2]. In the meantime, while there are people who are enthusiastic to keep track on their data (e.g. the Quantified Self movement [3]), the rest of them may not always feel interested or motivated to engage with their data [4]. Such complexity makes it challenging to address the issue of personal data awareness.

Under this context, we proposed a novel method to tackle the data privacy dilemma, to bridge users' concern and distrust in their interaction with data and to increase their awareness and understanding of personal data, that is, leveraging embodiment to build the sense of data ownership.

As a constantly discussed topic, different attempts from different aspects have been made to enhance people's understanding and awareness of data privacy. However, legal systems are not sufficiently agile to respond to the situation, and self-initiated proposals have been ineffective in stopping the practice of data tracking and analysis from users [5]. In the design field, current studies have been focusing on personal data management and curation [13, 20, 21], which are solely based on screen-based devices and virtual environment. There is little research that focuses on using physical objects and tangible interaction to increase the understanding and awareness for data, while some prior study has found out that the physicalization of data can be very effective in helping people reflect on their data [18] and increase their engagement with the data [16].

Therefore, we explore how people perceive and interact with data, as well as the concerns and find challenges [25], and physicalize such understandings and interactions into an interactive installation [11].

We propose a conceptual installation 'DataCity', which presents personal data embodiments using the metaphor of building one's own city to leverage the physicality. We have been focusing on the following criteria:

1. Increase the sense of owning one's own data through data physicalization
2. Facilitate users to understand better about their personal data through a boundary
3. Provide playful and reminding signal to foster the engagement with data

The following sections describe the details of this paper: Sect. 2 presents the related work of this study. Section 3 describes the research methodology as well as the key insights, explains the design and system structure, and demonstrates the user testing results. Section 4 illustrates four different interaction modes. Section 5 and 6 give a detailed discussion and conclusion about the project concerning possible future work.

2 Related Work

The trend of collecting and analyzing digital information has brought to a new discussion of the interaction between human and data. Human-Data Interaction (HDI) aims at investigating how people interact with data as an analogy with how Human-Computer Interaction investigates the relationship between people and computers [6]. Recently, to address the challenges in HDI, Mortier et al. [12] have proposed three key aspects for meaningful interaction with data – legibility, agency and negotiability. Legibility concerns making data and analytics algorithms both transparent and comprehensible to the people who care about their own data and how they are being processed. Agency concerns giving people the capacity to act within these data systems, to opt-in or to opt-out, to control, inform and correct data and inferences, and so on. Negotiability concerns the many dynamic relationships that arise around data and data processing.

To help people explore, understand and manage digital information, embodied interaction is emerging as a research topic. In this aspect, different applied scenarios are discussed, such as using embodied interaction for exploring and learning datasets at a museum [1] or for urban planning with augmented reality [15]. The Shape-Changing Interfaces [14], as a proof-of-concept prototype, also provides a physical experience to feel and manipulate data. These studies have proven the effectiveness of exploring and understanding data with immersive and physical experience. However, most of the existing studies focused on understanding open or public data. There is still limited study on designing embodied interaction for personal data, with particular concerns on privacy awareness.

Data embodiment is tightly related to data physicalization, which is defined as using a physical artifact to encode and represent data. Although data physicalization is closely connected to data visualization and tangible user interfaces, it focuses on data analysis in a physical form [8]. Prior studies have investigated the effect on how data physicalization can help people reflect on data by building personalized artifacts [18]. Moreover, there are a lot of different projects that turn data into physical artifacts, such as the use of LEGO bricks, 3D printed data sculpture or even handicrafts. Such physicalization can address on the non-visual senses and make data analysis more accessible [8].

Besides making data accessible, ensuring data, especially personal data, safe and private is another well-discussed topic in HDI. Begin with the privacy by design framework, most of the studies in data protection focus on the system structure or the data life cycle framework. In system design, DataBox [13] by Haddadi et al. and Virtual Walls [10] by Kapadia et al. both leveraged the metaphor of containment, which can be considered as the common physical encapsulation of data. Meanwhile, Hornung et al. [6] proposed a semiotic framework for data life cycle, and Romansky [17] provided a similar framework for data life cycle in personal data protection.

Previous studies of personal data management have been focusing on virtual and screen-based interaction. Vitale et al. designed Data Dashboard [21] for personal data curation which focused on centralization and customization. My Data Store [20] by Vescovi et al. is another example that enables individuals to gain awareness and control on personal data. These applications provided meaningful ways to categorize and manage personal data, but the virtual representation is yet to have a sufficient impact on gaining awareness.

3 Design Rationale

In order to design a meaningful interaction for personal data, a qualitative research approach was applied, including an online survey, a semi-structured interview and a participatory workshop. The idea of data ownership was raised in the survey and interview. It was also consolidated during the workshop and refined after the user testing. Eventually, the findings led to the design of DataCity.

3.1 Survey and Interview

We conducted an online survey (N = 93) and a number of semi-structured interviews with individuals (N = 10) who is concerned with their own data. The survey and interview aimed at investigating the general understanding of people's interaction with personal data.

The survey included 14 questions about an individual's daily habit of using digital devices and their attitude towards personal data collection, while the interviews were more detailed with follow-up questions. Each interview took roughly 45 min and was audio-recorded. The interview participants were from different professional backgrounds with an average age of 28 years old.

The findings from the survey and the interview revealed people's perception, behaviour and attitude towards personal data. To be more specific, we conclude that instead of data privacy awareness, the most significant issue in people's daily interaction with data is the lack of the sense of ownership, which is mainly caused by following factors:

- **The difficulty in understanding data or the process behind it.** Data and its backend process (life cycle) are always abstract and opaque. They require a high level of expertise to understand.
- **The passiveness in engaging with personal data.** Novice users tend to act passively in the interaction with data, which on the one hand, is because of their limited capability to manage and control data, and on the other hand, since the operations given by third-party service providers is also limited.
- **The lack of meaningful insights provided by the system.** Although a huge amount of data about the user is generated, there is no sufficient way for users to gain insight from the data, which also makes users lose the sense of owning it.

3.2 Participatory Workshop

Following the survey and interview, a participatory workshop, also based on the concept of data ownership, was conducted. The workshop aimed at finding the suitable physical form of data that can address the awareness of ownership. Four participants were recruited to the workshop, among whom there are three designers and one engineer. During the workshop, participants were asked to create a physical representation of their personal data out of clay and other materials that they prefer. A discussion on the interaction with the physical object as well as the way to protect it was followed. Eventually,

the participants were divided into two groups and groups designed two unique artefacts separately (Fig. 1).

Figure 1 left shows a design of a data bookshelf, which contains different partitions used for a different purpose, like displaying memorable personal images or containing locked and hidden secret information. Figure 1 right shows a data eraser and a data message-in-a-bottle, both of which are used to delete the unwanted or secret data, such as browser history.

The workshop has provided useful insights into building a sense of data ownership. First, the physical boundary and relationship of containment help users to gain the understanding and sense of control of their own data. Second, the sections which serve different functions also add to the sense of data ownership. Third, allowing physical manipulation such as re-arranging, keeping and discarding data can also contribute to the sense of ownership.

Fig. 1. The artifacts on data ownership workshop

3.3 Design of DataCity

Based on the findings above, we create an embodied interaction design, DataCity. DataCity (see Fig. 2) is an integrated system including a physical installation and a mobile application. The application is an entry point of the system which is connected to other mobile applications on the user's phone, and the installation is where the user performs interaction with data (see Fig. 3). The concept of DataCity is to use city building as an approach to physicalize user's personal data on their mobile devices, encourage the user to watch over and perform physical manipulation to the city she builds, and eventually gain the sense of data ownership. The interaction can be divided into two parts, one is the digital interaction via augmented reality on the mobile application, the other is the physical interaction via tangible manipulation.

The features of DataCity are designed according to the design insights obtained from the qualitative user research, which are:

– Provide physical representation using a series of metaphors for users to gain a better understanding of their data

– Encourage users to explore their data by themselves by building their own cities in a gradual process, which helps to build the proactiveness in the interaction with data
– Provide useful insights (e.g. notifying data breach) in a novel and interactive way.

Fig. 2. The mobile application and the installation of DataCity

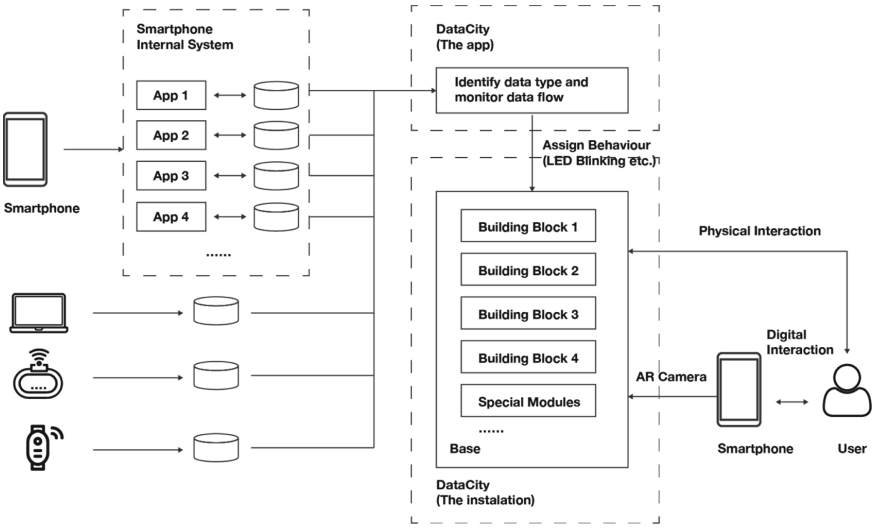


Fig. 3. System diagram of DataCity

To increase the user's sense of data ownership, designing an intuitive and natural interaction is crucial. A city building metaphor is chosen because it is a common form in business simulation games, and some mobile applications use city building to perform certain kinds of behaviour change such as spending management. The proper linkage between the city blocks and the data it represents has to be intuitive. At first, we have different ideas of linking the mobile personal data to the buildings. After user testing,

Table 1. Components and their representations in DataCity.

Component	Physical Object	Virtual Representation / Usage
DataBlock		The eight different types of personal data on mobile apps The type is represented by LED
DataBuilding		The mobile applications on the user's smartphone It consists of multiple DataBlocks which depend on the application
Fences		Sensitive data protection It is a special module that is used to protect certain the sensitive data of certain DataBuilding
Incinerator		Data deleting It is a special module that is used to delete the data contained within a certain DataBlock
Fountain		Data displaying It is a special module that is used to display the data the user wants to showcase (such as memorable images) which would be seen in the AR view
Home		Data backup It is a special module that is used to copy or move the target data to an external storage

one of the ideas is chosen and further developed, which is shown in Table 1. This representation has a clear boundary and a containment relationship.

The eight types of data are defined as follows: media (photo, video, audio etc.), text (message, email, SNS post etc.), location (GPS location), health (Biometrics, health tracking data etc.), finance (banking information, credit cards etc.), social (contact, connections), log and cache (browser history, use logs), account (profile, demographics etc.). It is worth mentioning that there are a lot of different categorizations regarding personal data, for example, Haddadi et al. [5] analyzed one of the researchers entire digital footprint, and concluded with 5 data types: communication (email, instant messaging etc.), financial (bank statement, credit card statement etc.), family (photographs, trips, etc.), individual (personal location traces, personal calendar etc.) and online social networks (Twitter, Facebook, Google+ etc.). However, this categorization is relatively personal. Other categorizations might focus on the semiotic meaning of personal data [19] or the sensitivity of data [7], which is too concise for personal use. Therefore, we decide to use our own categorization which mainly comes from one of the questions from the user research that asked about *"what kinds of data do you check and track in your daily life"*.

3.4 User Testing

To ensure the design concept matches the criteria of our design goal, we conducted two rounds of user testing. The first round focused on the form of the linkage be-tween mobile the personal data and the DataBlocks and was tested before finalizing the design of DataCity, while the second round was conducted with the AR application and mainly focused on testing the interactivity of the overall system.

During the first-round testing, different ideas of linking the data and the city blocks were considered: a) each block represents one mobile app and the colour of LED shows the types of data access in real-time; b) each block shape represents one type of applications, the LED shows the data access and each building represents one mobile app; c) each block shape represents one type of data, the colour of LED shows the types of the mobile applications and each building represents a cluster of the same type of data access in real-time. We invited test users to build a DataCity using these three forms and asked them to rate the intuitiveness, effectiveness and clarity of the ideas and to leave comments. According to the feedbacks, keeping each building as one shape and using the number of blocks to indicate the level of data access is more user friendly and has a clear containing hierarchy and boundary. Eventually, we have chosen b) as our design.

In the second-round testing, we asked participants to build the blocks together with the DataCity mobile application using the think-aloud protocol. As they performed the tasks, we collected useful insights that helped refine the design. First, according to the participants, more clear instructions and call-to-actions of the flow is preferred. Second, as they enjoyed the process of building the city, customization and more interactivity on the screen is desired. Moreover, they also indicated small details of improvement such as the unclear visual effect or the position of the LEDs. We collected these results and finalized the overall design and interactivity of DataCity.

The ways of how to interact with DataCity will be introduced in the next section.

4 Interactivity

With the mobile application and the installation set up, the user can start to interact with DataCity. Synthesizing the results from the user research, we define four key functionalities for meaningful interaction:

1. Giving Consent
2. Monitoring
3. Protecting
4. Managing

The functionalities above reflect users' needs for data ownership. Giving consent and monitoring are two main functions related to the users' concerns from the survey and interviews which aims at increasing the proactiveness and sense of control of the users' personal data. The remaining two functionalities, protecting and managing, are tightly connected to the workshop insights, allowing users to curate, save and discard their data in physical form.

Each of these functionalities requires the physical interaction with DataBlocks, and some of them require digital interaction via augmented reality on the user's phone. The detailed description is listed in Table 2.

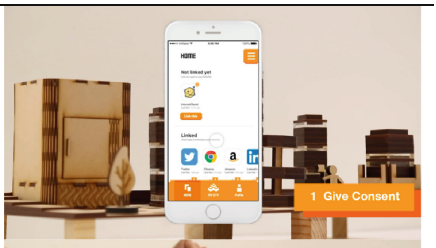
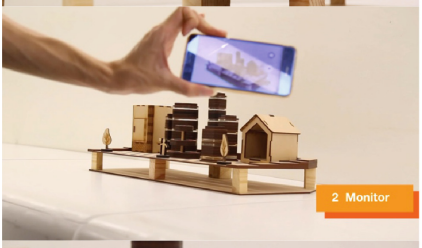
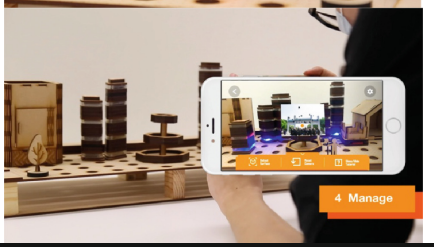
Giving Consent. Every application on the smartphone would ask for permission to access data, and there are already a lot of discussions on how to design for consent. In DataCity, we propose an interaction that allows users to give consent to a certain type of data only by layering blocks and eventually form a DataBuilding. When a new app is installed, DataCity intercepts its request for data access, showing how many different types of data are being requested and asks the user to put on blocks to build the building. The building consists of at least a base which represents the user account, and other data if any, and shows the data type by blinking the LED inside. It adds friction in giving the consent which we believe is a way to increase the sense of data ownership.

Monitoring. Monitoring is another function that leverages the physical objects and their attributes. Once the DataCity is built, users can check the status of their city both physically or via smartphone AR view. Physically, the user would see the data flow indicated by the blinking LED. When the data traffic is huge, the brightness of the LED will be higher accordingly. When checking via smartphone AR view, the user can see three different special effects indicating three different situations. When there is ivy on the building, it means the data is not accessed for a while. When thick clouds are surrounding the building, it means the related app is constantly sending huge data to the cloud. If the user sees water leaking on the building, it means the data might be exposed to malicious third-parties and needed to be repaired (Fig. 4).

Fig. 4. Three special effects on the AR view

Protecting. Once the user spotted the abnormal behaviour of the data, she can protect the DataBuilding by putting a Fences module under it. The Fences module acts as a

Table 2. Key functionalities of DataCity.

	Description	Demonstration
1	**Giving Consent** User is asked to build a new building when a new application is installed. DataCity shows the request for data access from the application, and the user gives consent by putting blocks on the building.	
2	**Monitoring** User uses the AR camera to scan DataCity, spot the animated special effects shown on the AR view and check the abnormal data behaviours from each application.	
3	**Protecting** User puts the Fences module under the building she wants to protect and set the sensitivity setting. The sensitive data that are uploading would be blocked and waiting for approval.	
4	**Managing** User uses three modules to perform delete, display(decorate) and backup using physical manipulation.	

filter. It blocks the data type which is set sensitive by the user from uploading and waits for the user to check and approve. For example, the user sets location data as sensitive data, and the protected app is a social media platform. Once the user posts something accidentally with the location information, the post would be blocked and wait for the user to confirm to send. Meanwhile, the red LED on the Fences would blink to warn the user.

Managing. Besides the functionalities above, the user can manage their data use three special modules. The incinerator is a metaphor of the city's refuse destructor plant. The user can throw a DataBlock inside, and the sensor detects the object and send a confirmation message on the phone, the user confirms the deleting process, and the data within the DataBlock will be deleted. The Fountain is a metaphor of the city square, which is a place for the user to decorate and display the information they want to show on AR view. For example, a memorable photo can be shown, and the user can take a screenshot or video of their own city and share to others. The Home module is similar to the incinerator; however, it is mainly used to store or backup the data. User can put the DataBlock inside the Home module, and similarly, a notification will be sent to the user's phone, and the user confirms to copy, move or cancel. After that, the data will be stored in an external hard drive.

5 Discussion

We propose a novel embodied interaction design to increase novice users' sense of data ownership, and we are envisioning that this can be the first step to a better understanding of personal data. We hope that, eventually, it will enhance people's privacy literacy and promote a better human-data interaction. Despite the fact that this prototype is unique and interesting, there is still a lot of space for discussion and improvement.

5.1 The Effectiveness of the Prototype

DataCiy is a sample application to demonstrate our idea of building users' sense of data ownership, and the prototype was tested with participants during user testing. Through the think-aloud protocol and observation, we found that users need better guidance besides the tutorial on the mobile screen, which indicates the improvements of design of the blocks. In addition to this, some of the participants also reported that they have an unclear understanding of some of the visual metaphors such as the cloud effect on the AR view. It implies that these metaphors should be more carefully defined as people have different perceptions towards it. Apart from these, participants enjoyed playing with the prototype and have no doubts about its functionalities, including building, monitoring and performing tasks using the special blocks. The participants all reported the increase in the interests of engaging with their personal data, as well as the sense of owning them, which helped prove the initial effectiveness of the prototype. However, further observations and discussion should be included and the trust and acceptance of DataCity should be tested after the prototype is able to connect to the data in a real scenario.

5.2 The Pros and Cons of Tangible User Interface

Although studies have proven that a physical manifestation of data is very powerful in helping people understand the complexity of it, there is still limitations of the tangible user interface (TUI). First of all, it is hard to install, store or display physical installations, especially within the home context. Though assembling and disassembling blocks is effectively effective to foster users' engagement, but it could also be burdensome. DataCity could further be developed into a demonstrative installation in public spaces such as museums, as to increase the awareness of the public. Another possible form of development of DataCity is a home-use lego-like toolkit that is easier to assemble or disassemble. Second, there is a significant limitation for physical objects. Unlike Graphical User Interface (GUI), objects with a tangible interface cannot change its shape or colour etc. It could be useful to represent more diverse information of the data. In DataCity, we used LED lights to represent the data type. To leverage more physical attributes, we may need to rely on new technologies such as shape-changing interfaces. In order to address these issues, a lighter and refined design of the tangible component should be considered as a further development direction.

5.3 The Need for Long-Term Development

From survey and interviews, participants have expressed the need to understand data better and to know how to protect their data. We understand that as a part of the privacy literacy, this needs long-term development and improvement. Although during user testing, DataCity has been reported to be fun to play with, however, we could not test the long-term effect of it. In fact, further investigation is needed to explore whether the design can nurture people's understanding and sense of control of their personal data within a longer period of time, and incentives should be considered to maintain the user engagement.

5.4 Further Improvement of Data Aggregation and Categorization

One of the main efforts in developing the concept of DataCity is about how to convert personal data on a smartphone into tangible objects. Although the smartphone is the biggest source of personal data, with the development of Internet of Things and various kinds of wearables devices, data from other sources will become more and more important in the future. Including data from different personal devices, perform proper categorization of them has become another direction for further development. As there is still limited research in the aggregation and categorization in personal data from different sources, it relies on the development of edge computing to perform the aggregation and categorization. Therefore, it is a future challenge that needs researchers from different backgrounds to tackle.

6 Conclusion

To conclude, we build a physical embodied interaction to help people understand data and have a better sense of control of it. We believe it would contribute to building a sense

of data ownership and develop people's privacy literacy. The data-driven paradigm has just begun, and there is still a lot of space for design to either improve the awareness or to improve the human-data interaction. All in all, we believe that the most important principle in developing future digital products and applications is to put the user in the centre of the interaction among all the devices. DataCity is an attempt to practice this principle, and more interactive experience is needed to push this concept further and further.

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