

# Toward a Framework for Ecologies of Artifacts: How Are Digital Artifacts Interconnected within a Personal Life?

Heekyoung Jung, Erik Stolterman, Will Ryan, Tonya Thompson, Marty Siegel

Indiana University

School of Informatics (HCI Design)

919 E. 10th Street, Bloomington, IN 47408, USA

{jung5, estolter, wnryan, tstroman, msiegel}@indiana.edu

## ABSTRACT

Assuming that an interactive artifact cannot be fully understood by itself due to their increasing number, we explored how individual artifacts are related to each other and how those relationships can be investigated for further design and research implications. This study suggests a concept of *ecology of artifacts* to describe any implicit or explicit relationships among interactive artifacts in one's personal life. We conducted two types of studies – *personal inventory study* and an *ecology map study* – to explore multiple dimensions for understanding a personal ecology of artifacts. We expect the knowledge of artifact ecology would help designers and researchers in the field of HCI to create and analyze interactive artifacts considering their dynamic interplays in an increasingly ubiquitous technology environment.

## Categories and Subject Descriptors

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

## General Terms

Design, Theory

## Keywords

Artifact, personal ecology, interactivity, design

## 1. INTRODUCTION

Our reality is becoming increasingly interactive and flooded by new interactive artifacts and traditional artifacts enhanced by digital technology. A person uses a number of digital artifacts for a variety of daily activities including work, communication, entertainment, etc. As interactive artifacts are pervasive and influential to various aspects of human life, the interconnected use of multiple interactive artifacts needs to be investigated in order to fully understand their meanings and values in human life beyond

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NordiCHI 2008: *Using Bridges*, 18-22 October, Lund, Sweden.

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technical and functional influences. An increasing number of artifacts communicate with each other, exchange information, and share content and data [5, 8, 21] creating a *network* of artifacts. The reality of being a user of “not one distinct artifact,” but of a large set of interconnected artifacts is a growing concern that has not received enough research attention even though these intricate and complex relationships among artifacts have been addressed by researchers from different fields [14, 15, 18, 27, 30]. We have found that most existing approaches in HCI or related fields are based on the notion of a single well-defined artifact in relation to a single user or possibly a group of users (for overviews see Carroll [4] and Rogers [32]) instead of addressing the issues emerging from considerations of networks of interactive artifacts.

This study started from an assumption that digital artifacts are interconnected both in terms of their functions and meanings [6] surrounding an individual life. As interactive computing technologies more deeply pervade into everyday objects, we, designers and researchers in the field of HCI need to improve our ability to create and analyze these artifacts, especially considering their relations to other artifacts, our social and physical environments and human life [10, 25].

In this paper, we suggest that a productive way to understand such a network of artifacts and its influence on human life is to examine it as an *ecology of artifacts*. We define a *personal ecology of interactive artifacts* as a set of all physical artifacts with some level of interactivity enabled by digital technology that a person owns, has access to, and uses (Fig 1). One assumption in this study is that the notion of *ecology*, with its biological roots, serves well both as a metaphor and as a theoretical construct to support the examination of complex networks of interactive artifacts. Based on this assumption, this paper aims to explore appropriate methods to investigate ecology of artifacts focusing on how to describe and analyze those dynamic relationships.

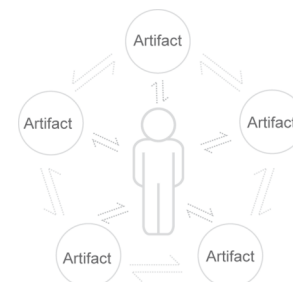


Fig 1. A Personal Ecology of Interactive Artifacts

## 2. OBJECTIVES

Every newly designed interactive artifact will inevitably become a part of someone's ecology. The challenge for any interaction designer is to know how to think about a specific single artifact in relation to its ecology [20]. There already is an intense "competition" among artifacts for a place within these ecologies, and only those devices which provide the greatest value in an ecology will be sustained.

We are convinced that interaction designers, in most cases, do not have explicit strategies for dealing with these interconnected relationships among artifacts except for when it comes to technical infrastructural aspects or data synchronization across multiple devices [7, 31, 33]. There are neither theoretical nor practical approaches, as far as we know, for how a number of devices should or could be designed to fit in an ecology of artifacts. As an initial approach for studying an ecology of artifacts, this paper will introduce a theoretical foundation of artifact ecologies while considering the influence of interconnected artifacts in human life. Then, we will investigate any factors or elements that can be used to describe a personal ecology of artifacts based on the results from exploratory studies.

Specifically, this exploratory study consists of two parts, *the personal inventory study* and *the ecology map study*. The personal inventory study is to investigate multiple dimensions of properties and values in using interactive artifacts through semi-structured interviews. The ecology map study is designed to examine people's mental model toward the meaning and relations among interactive artifacts through visualizing the maps. Results from both approaches are ultimately aimed to suggest a conceptual foundation for the study of an ecology of artifacts and to discover particular issues that would emerge when artifacts are considered in relation to each other. However, the purpose with our studies at this stage has not been to generalize patterns of using digital artifacts nor to solve their specific problems.

We expect that understanding the concept of artifact ecologies would lead to knowledge about how people experience and strategize the use of interactive artifacts and the development of their ecologies over time. Accordingly, this knowledge would support practice and research for analyzing and designing new interactive artifacts considering the complex relationships of an artifact to other artifacts and to its external environments.

## 3. THEORETICAL FOUNDATION

To ground our study, we reviewed several theoretical studies for our study of artifact ecology. Specifically, a philosophical foundation about relations among humans, things, and their reality inspired us to bring the fundamental importance of understanding the influences and relations among interactive artifacts into focus. Related studies that employed ecological perspectives in the field of HCI were also briefly discussed.

### 3.1 Conceptual Grounds on Artifacts

While the philosophy of technology has extensively explored how humans relate to their reality, there has been less interest in the more concrete relationship between humans and their artifacts. In recent years, however, we have seen several new theoretical attempts in the philosophy of technology bringing artifacts and "things" into focus. These attempts create an overall framework or map of existing philosophy on new technologies and artifacts. All attempts mentioned below can be viewed as a striving towards

what Mitcham [22] labels as a phenomenology of artifacts. He describes this school of thought as dominated by the idea that technology can be studied as consisting of artifacts with inherent designed qualities and, once placed in the world, evoke a space of possibility and limitations to its environment and its users.

From the works of Verbeek [35], we have been inspired by the notion that things "act." This is not an approach that makes artifacts "alive," but it does recognize the inherent behavior, particularly of digitally enhanced artifacts, that make them able to recognize their environment and act accordingly. From Borgmann [3], our approach has been influenced by his famous notion of the device paradigm. According to the device paradigm, there is a disconnection between the way we design modern artifacts and what people need to feel grounded in contact with their reality. He argues that such a development restricts people from having close relationships with artifacts in a meaningful way. From Latour [18], we understand the notion of networks as aligned actants where artifacts in the network work in close relationship with humans to create combined realities shaping each other.

It is obvious that these scholars cannot easily be combined into a coherent theory, and that is not our purpose. However, we fully recognize that any examination about the relationship between people and artifacts rests upon a philosophy of technology, whether conscious or unconscious. As artifacts are becoming more interactive and even autonomous in increasingly ubiquitous and pervasive computing environments, a philosophical stance regarding artifacts offers designers and researchers in HCI insights and "tools" to reinterpret their meanings and influences from different perspectives that go beyond the more typical technology-oriented or user-centered points of views. This motivated us to investigate inherent properties and values of artifacts that would influence human life and reality.

### 3.2 Ecologies of Artifacts

As a core and fundamental concept in our study, we have chosen the notion of *ecology*. Some researchers have previously taken the ecological perspective to study human artifacts, since the metaphor provides meaningful analogies to explain complex interactions among artifacts, humans and environments. Gibson introduced affordance theory to explain how the environment influences the visual perception of humans providing an ecological foundation for designing new interactive artifacts in usable ways [11]. Nardi and O'Day defined the concept of *information ecology* as a system of people, practices, values, and technologies in a particular local environment [24]. Forlizzi introduced the concept of *product ecology* to analyze the social use of products [9]. Based on social ecology theory, she specified various interacting factors in a product ecology including people, activities, the built environment, and the social and cultural contexts, which can be used as a framework of designing social product. Krippendorff has emphasized the *ecological meaning* of an artifact as consisting of its possible interactions with other artifacts, which successively evolve while guiding particular users' choices, driving an increase or decrease of species of artifacts, and thus transforming everyday life [17]. The message from these authors is that designers need to consider the ecological consequences of an artifact, not only its independent visual or usable qualities, when creating a new artifact.

### 3.3 Ecological Concepts in HCI Research

As research on mobile and ubiquitous computing is increasing in the field of HCI, more integrative perspectives are required to investigate the relations between artifacts and their diverse contexts of use. Although several studies do not directly mention the terms of ecology, their approach to analyze interconnections among multiple devices provides insights for ecological concepts to this study. Oulasvirta et al. [29] suggested the concept of mobile kits to solve problems of managing multiple devices focusing on physical handling of devices and cross-device synchronization. In another article [28], he also introduced broader issues of context-awareness, seamlessness and non-disruptiveness when multiple devices work together in ubiquitous computing environment. Mainwaring et al. [19] investigated the relationships among people, places and services when using mobile kits through various urban interfaces. Their study considered ubicomp as a paradigm of trusted and environmentally embedded computing emphasizing its increasing influence on everyday environment. Dearman et al. [7] focuses on the personal computing with multiple devices suggesting design implications for task and context-oriented device usage rather than application-specific usage. As those studies indicate, mobile and ubiquitous computing is hard to be investigated without considering its interconnections with environment and other artifacts as an ecosystem. Based on previous studies, this study aims at suggesting a common ground to describe and understand the artifact ecology with an analytic framework.

## 4. METHODS

Based on the theoretical foundation, we conducted exploratory studies to get more detailed insights about any perceived relations among digital artifacts. As an exploratory attempt to develop a preliminary framework for studying artifact ecologies, our study mainly investigated how people consider their interactive digital artifacts and any ecological concepts among them.

The exploratory study consists of two parts, *the personal inventory study (PI)* and *the ecology map study (EM)*. 5 sessions of pilot studies were conducted to refine the study process and methods before the real study. 10 subjects participated in the actual study and each session took about 90 minutes (60 mins for the PI and 30 mins for the EM in overall). All participants were from the department of Human Computer Interaction Design (all graduate students, 5 men and 5 women) at our university. Assuming that they are interested in new computing technologies with diverse backgrounds (i.e. industrial design, computer science, information systems), we expected this group to be more appropriate for finding grater dynamic usages of various digital devices compared to average user groups.

### 4.1 Part 1: Personal Inventory Study (PI)

The first part, the personal inventory study, is aimed at investigating what digital artifacts people own and how they use and value each of these artifacts. Referring to the Repertory Grid Technique (RGT) [13], we conducted semi-structured interviews with individual participant. The RGT is a method of elucidating the personal construction of her or his environment (i.e. artifacts, other persons) based on semantic differentials (i.e. bad-good, isolated-connected). Considering its appropriateness to explore multiple dimensions of design space from idiosyncratic perspectives, we modified the method in a simpler way to understand what people are mainly concerned with about each of

their artifacts without revealing any intent to investigate ecological aspects. Instead of using a couple of opposite adjectives, we asked participants to select particular adjectives to understand aspects of using digital artifacts from their subjective perspectives and also to analyze interview data more efficiently.

In the beginning, the participant was asked to list every interactive artifact they use on a post-it card and to select adjectives that describe each artifact the best. Example adjectives were given to cover various dimensions of properties of interactive product such as physical appearance, usability, functions, etc., but the study was also open for participants to come up with their own words. Table 1 shows the list of example adjectives. In the end, the participant was asked to describe detailed reasons for selecting some adjectives as a debrief session. This study provided us with a quick understanding of people's overall use and reflective response about each artifact. More importantly, it provided us meaningful insights about the influence of digital artifacts in a personal life and implicit relationships among different artifacts, which will be discussed later.

### 4.2 Part 2: Ecology Map Study (EM)

As an extension of the first part, sketching methods were employed to visualize relationships among personal artifacts as an ecological map. Sketching has been frequently used to discover people's implicit conceptions toward complex topics [34]. As the concept of ecology is very new and hard to be articulated, we expect that methods of visualization would be appropriate to reveal implicit relationships among artifacts, complementing the interview results from the personal inventory studies. The ecology map study was done in a simplified way of sketching by using artifact-labeled post-it cards, which were made in the previous part of the personal inventory study.

Hard	Stable	Soft	Unstable
Heavy	Safe	Light	Dangerous
Mechanical	Friendly	Emotional	Unfriendly
Compact	Primary	Large	Secondary
Flexible	Professional	Rigid	Relaxing
Attractive	Remarkable	Ugly	Mundane
Young	Private	Old	Public
Clean	Manageable	Dirty	Scattered
Neat	Duplicable	Shabby	Irreplaceable
Reliable	Secure	Fragile	Vulnerable
Economic	Connected	Luxurious	Isolated
Lovely	Redundant	Poor	Essential
Portable	Relieving	Stationary	Nervous
Sensitive	Fast	Unresponsive	Slow
Handy	Useful	Inconvenient	Useless
Simple	Advanced	Complicate	Elementary
Playful	Valuable	Serious	Worthless
Easy	Efficient	Difficult	Boring
Obtrusive	Helpful	Calm	Burdening
Encouraging	Smart	Discouraging	Dumb
Exciting	Time-consuming	Multi-purpose	Single-purpose

Table 1. List of example adjectives to describe each artifact

We did not give any specific instructions for drawing the maps, but asked participants to attach post-its labeled as artifacts on a whiteboard according to any relations they have conceived, to draw any graphic elements (e.g. line, box, circle), and to write any notes to express those relations more clearly. A white board was used so that subjects could draw or write any comments and edit them. Many of participants were not sure what or how to draw at first, while others categorized their artifact-cards on the board very quickly. Despite these differences, the study results led us to meaningful insights about personal ecologies of artifacts.

## 5. RESULTS

In this section, we describe the results of our analysis of the user study - both from the personal inventory study and the ecology map study. As mentioned earlier, the purpose of our study was not to find general patterns or problems of using digital artifacts in our everyday life. Instead, it was an exploratory study with a purpose to investigate if any ecological concepts are perceived or described by users when they describe their use of digital artifacts or if any emergent patterns could be discovered when considering the artifacts in terms of ecology.

The goal of analyzing the results is that it will lead to a preliminary framework to understand the concept of artifact ecologies, to explore methods for studying it, and to discover any important issues that need to be further studied. Therefore, the findings from the study may not necessarily be something new but already familiar to us. However, we have looked for signs that would reveal new design and research issues from an ecological perspective. Specifically, the results were analyzed by focusing on two points. First, we investigated all the particular properties or values of single artifacts from which people construct *relations* among artifacts. This is mainly done based on the analysis of the personal inventory study. Second, we analyzed different groupings of artifacts with regard to their purposes or contexts of use based on the ecology map study.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	SUM
Desktop PC	1	1	1					1	1		5
Laptop	1	1	1	1	1	1	1	1	1	1	10
Flash driver			1		3	1		1	1		7
Printer		1	1		1		1	1	1	1	7
Mobile phone	1	1	1	1	1	1	1	1	1	1	10
Digital camera	2			1	1	1	1	1	1	1	9
Mp3 player	3			2	1	1	1	2		1	11
Voice recorder	1				1	1	1	1			5
Game system			2						3		5
GPS navigator			1					1			2
Television		1	1			1	1	1	1	1	7
Home theater								1		1	2
DVD player		1					1	1		1	4
Cable box		1						1			2
Others	3	1	2	4				5	1	3	19
Total	12	8	11	9	9	7	8	19	11	11	105

Table 2. Number of artifact items for each participant

## 5.1 Results1 (from PI)

A total of 105 items of interactive artifacts were mentioned by 10 participants. The selection of “digital interactive artifacts” was quite dependent on participants’ subjective decision. We asked them to include any types of interactive artifacts using digital technology that they frequently use or consider important to their life. Portable devices (i.e. laptop, mobile phone, digital camera, music player) were mainly mentioned considering the lifestyles of our participants as graduate students. Other items included headsets, computer monitors, mice, hair dryers, microwaves, coffee makers, vacuum cleaners, thermostats, etc. Although some of them may be not directly related to ‘digital technology’, we included them in the study considering their subjective importance to participants. During this study, we did not mention any ecological concepts to participants. Table 2 shows the number of artifacts that each participant (P1, P2, P3, ..., P10) mentioned.

We analyzed the results from the personal inventory study by coding every single adjective that participants selected from the list and all additional comments mentioned to describe each artifact. First we categorized the adjectives and comments into similar types regardless of artifact types. Some of them were about attributes inherent in the artifact - *designed properties*, while others were about personal reflections on artifacts - *subjective values*. We are aware of the difficulty of making these distinctions, both philosophically and practically, but here we use them as a first way of organizing our results.

Our scheme resulted in over 700 codes in seven groupings- four types of artifact properties (*physical, interactive, functional and informational*) and three types of subjective values (*experiential, emotional, and social*). Some of codes belong to more than one property or value considering their interconnected relations. In that case, they are counted as separate codes. The rationale for coding the study data to properties and values is to suggest a holistic perspective to compare and analyze various types of digital artifacts with general criteria. Those artifact properties and values form a tentative framework to organize some core aspects of an artifact ecology.

### 5.1.1 Properties of artifact

Properties are perceived attributes inherent of artifacts. Based on some earlier preliminary research we categorized them into *the physical, the functional, the informational and the interactive* covering various aspects of user perceptions toward different types of artifacts. The *physical aspect* is the artifact as a physical manifestation, as a thing; for instance, the laptop, the cell phone, or the mp3 player. Any descriptions about physical size, weight, appearance or interface are categorized into this property. Sometimes, aesthetic qualities from artifact appearance are linked to artifact’s emotional value (i.e. cute, attractive, awesome). The *functional aspect* of an artifact refers to what an artifact is used for. Comments about practical aspects of using artifacts, such as task, performance, or features are categorized into this functional property. The *informational aspect* is similar to the functional with the difference that it is about data or content, instead of functional application. Direct comments about data, information, or contents created or stored in an artifact are categorized into the informational property. The *interactive aspect* is the way a person can interact with a physical artifact. Issues related to usability or ease of use are categorized into this property.

### 5.1.2 Values of artifacts

Although value can be interpreted in many ways [10], in this study we focused on its subjective and reflective aspects as being derived from the use of the artifacts, which is closely related to Norman's concept of reflective responses [26]. We discovered three criteria of values from the study data: *the experiential, the emotional and the social*. *Experiential value* is connected to personal memories or reflective responses toward an artifact. *Emotional value* is related to how a participant feels toward an artifact as in the overall impression or character of the artifact elicited from all perceived properties of a specific artifact [16]. *Social value* is about symbolic meaning or economic value of an artifact in a social context. In most cases, specific values are evoked from a particular property of artifact (if performance of an artifact is 'slow' or its interface is 'not responsive', people feel the artifact is 'dumb', which is reflected as an emotional value toward the artifact). However, regardless of artifact properties, they may value an artifact as "valuable" or "memorable" according to their long-term experience of use.

Coded data from the personal inventory studies provide a tentative framework to understand overall aspects of perceiving digital artifacts. With this framework, we could explore various dimensions of product properties and values (beyond prevalent usability issues) that can be used to describe a personal ecology of artifacts and any of their interconnected relationships. They will be discussed in the later part of findings section.

## 5.2 Results2 (from EM)

We also analyzed all the graphic or text items drawn in the 10 ecology maps and got over 100 codes of three types; *labels of grouping, graphic elements* to group or connect artifacts (circles, lines or arrows) and *annotations* to explain relations or connections among artifacts.

Participants grouped artifacts by posting several cards more closely together and others quite apart according to their perceived relationships. Graphic elements such as circles, lines, or boxes were often used to distinguish or clarify those groups but not always. We analyzed them focusing on participants' intentions of using graphic elements to represent different type relations. Sometime, they labeled each group according to reasons for those relations. The labels cover purpose of use ("work," "entertainment"), physical context of use ("home," "lab," "living room"), similar appearance ("minimal design"), same memories ("gifts"), technical relations ("computer," "camera"), etc. Some groups are left without any labels but still separately positioned apart from other groups. The types of labels and their relationships will be analyzed in the findings section. Text annotations—either descriptive sentences or brief words—were used to add detailed descriptions about the ecology maps. We also included verbal annotations, not only written messages on the board in our analysis. The results of the ecology map studies gave us more subjective ideas about the whole inventory of artifacts in relation with owners' identity or lifestyles.

## 6. FINDINGS

By analyzing details of the results from two studies (PI and EM), we observed interesting phenomena emerging from the relations among a group of personal artifacts. Specifically, some properties and values from individual artifacts display ecological factors, which shape the functional network or aesthetic commonality

among artifacts. Those factors are manifested as diverse patterns of use, which we named as layers of artifact ecology.

### 6.1 Ecological Factors (from PI)

From the personal inventory studies, certain properties and values of individual artifacts were mentioned especially in relation to other artifacts of the whole inventory. Although those properties are small in numbers compared to all the properties and values that describe characteristics of individual artifacts, they are noticeable as emerging factors when an artifact is considered as belonging to an ecology. They transform the use of individual artifacts when individual artifacts are connected to others. We define them as *ecological factors*. These factors "build" an ecology by making *connections* between specific artifacts or *commonality* throughout a group of artifacts. We will discuss those ecological factors emerging from each property and value.

#### 6.1.1 Connection through information sharing

Connection through sharing information between devices is one of the most significant ecological factors emerging from the informational property of digital artifacts. We found that it is common that participants use more than one computer (laptop, home PC, or public PC) and that they use other small devices such as external driver, music player, or smart phone to transfer the information around.

As many of digital artifacts are used as a group in connection with others, individual artifacts sometimes tend to be considered as parts of a higher system instead of separate independent ones. Accordingly, their role or importance is perceived comparative to each other. Adjectives describing individual artifacts such as "primary," "complementary," or "secondary" revealed their relative importance among the whole inventory items. In many cases, computer is considered as one of the most important artifact in personal ecologies described as "focal point" or "core."

[P3] "My laptop is a core of my computing system. I have a home computer, but almost never use that for my work. I have all my work data in this computer (laptop) and I can do so many things with it. It is the most important device for me."

[P4] "I have an iPod touch, but I rarely use it for music because I have another classic iPod. I use the Touch for checking my emails and schedules on the move or when I cannot use my laptop. I consider it as a part of my laptop, just for checking emails."

For several participants, it was found that web applications (particularly emails and schedulers) take an important role in connecting different digital devices.

[P2] "After I purchased my iPhone, I got more interested in harmonizing my laptop, iPhone, and my desktop through a web scheduler. I don't use my paper scheduler any more... My schedule is always updated through web in any of my devices."

What is interesting from this factor of connection through information is that people tend to appropriate digital artifacts according to their customized needs regardless of the initial design intents of artifacts. For example, as Participant 3 and 4 mentioned above, only a few features of an artifact can be selectively used according to its relative roles in its higher group of artifacts while other features of the artifact are remained unused. Similarly, it is noticeable that artifacts are separate in their physical manifestation; they are working like modules of a whole system linked by sharable and duplicable digital information.

### 6.1.2 Connection through functional compatibility

Regarding the functional property of digital artifacts, technical compatibility is considered as an important ecological factor that enables information sharing among different artifacts. Out of many comments on functional properties of artifact by participants, “connected” or “isolated” was frequently mentioned considering technical connections or constraints on data sharing among different digital devices. Participant 1 had the following to say that he has more than one portable music players, one of which he cannot use anymore as he had changed operating systems of the main computer.

[P1] *“I feel like my old mp3 player more and more isolated and useless. It does not work with my computer. I cannot download or upload any music. Actually, I do not need that anymore but I just keep that in my drawer. I don’t know what to do with that.”*

Also, some people mentioned they are satisfied with their laptops because they have sufficient number of USB ports that enable the connections with multiple devices at the same time. Similarly, display or sound devices are described as “flexible” because they can be used in connection with different devices.

[P10] *“Recently I purchased a new television for watching movies with my home theater system. But sometimes I use it with my laptop when working at home. It is better than to work with a small screen.”*

[P8] *“I think I use my home theater system more with my iPod than with DVD player. I have all my music there (iPod). I don’t want to listen to them through earphones even at my home.”*

Sometimes, a personal artifact can be even connected to others’ personal ecology through technical connections supporting social activities.

[P7] *“I always bring my iPod to parties at friends’. I can just plug my music to their computers (speakers). It is so convenient.”*

This factor of functional connection augments the use of a single artifact flexibly through customized combinations with different devices. On another hand, the compatibility of functional properties among different devices result in overlapping features across multiple devices. Many respondents selected adjectives such as “redundant,” “old” or “useless” as functional property or social value of an artifact. Most of them mentioned that they do rarely use all the features of their mobile phones (such as music player or camera). Several participants mentioned that redundant features with other artifacts are often make them hesitate when purchasing a new digital artifact with concerns on waste of technology (memory or storage space) as well as economic cost.

Surely there are trade-offs in device convergence between portability and quality of functions. In this paper, we do not argue the advantages and disadvantages of convergent devices or single-purpose appliances, but we emphasize some complaints about the lack of choices for users to select a device with features that they precisely need. Designers need to consider how to support to develop users’ personal ecologies based on their own needs and artifacts that they already have.

### 6.1.3 Contextual affordance and commonality

The physical and interactional properties are related to the commonality of using digital artifacts or specialized affordance of individual artifacts in diverse contexts of use. As people use a number of portable digital devices, such as laptop or mobile

phone, portability is considered as one of the most important physical properties for interactive artifacts in general. At the same time, due to the versatility of compact digital devices, people tend to have a couple of different devices that can work for the same tasks, for examples, digital camera and camera phone. Likewise, diverse contextual affordances make physical properties (i.e. weight, size, interface, etc) of artifacts more important to users when they select one device among similar ones. For example, participant 2 mentioned that the camera of his mobile phone is more useful when taking pictures to memorize some information (car numbers, street signs) just for the record on the walk, although he prefers to his digital camera in other situations.

In addition, the conceptual boundary between physical artifact and intangible digital content in it has been largely blurred. Sometimes digital contents tend to be considered similar with materialized “thing.” For example, participant 5 uses three flash drivers for saving different types of data (i.e. personal, work, entertainment). Her mental model of information structure is quite coupled to the physical entity of flash drivers.

[P5] *(pointing out each flash driver) “this is my personal data, this is my all my work data, and this is my music and movies. I have used these three flash drivers more than three years. So I remember almost of my data structure- which is stored where.”*

Participant 8 also commented that he usually said, “Here’s my music” when handing his iPod to his friends, indicating the entire play list inside the device. Participant 9 mentioned that he uses different computers to manage different types of data, which means separating work and leisure activities into different physical entities and contexts.

[P9] *“I only save my music files in my home computer. Actually I use it more like a music player. I use my laptop for more professional tasks.”*

The pervasiveness of information embodied in appropriate physical devices supports people’s ability to easily remember the structure of their distributed personal files without much cognitive burden [12, 21, 23]. The evolving definition of the relations between physical and informational properties opens up new design opportunities to embody appropriate physical and interactional properties to digital contents considering various forms of affordance and interactions to the contexts of use. Although those physical and interactional properties are not directly related to the informational or functional connections among artifacts, they set new common criteria where users’ need and expectations (such as portability or transparency) for interactive digital artifacts could be grounded on.

### 6.1.4 Ecological values changing behavior

Value criteria defined in the previous section (*emotional, experiential & social*) demonstrate influences of a set of digital artifacts on users’ behavior and perception towards artifacts and experience with them in general.

The introduction of a new artifact to an ecology can influence various aspects of users’ daily behaviors as well as the use of other artifacts. Considering the pervasive influence of digital devices that empower users to freely control digital contents (by accessing, creating and editing them), it was interesting that two of participants mentioned about spontaneous changes in behavior due to immediate access to or control of digital information by using a new interactive artifact.

[P8] “After using a DVR cable box, I feel like I cannot wait for something I do not want to watch. All TV programs are recorded, I don’t have to watch all of them. I usually skip most of boring parts and quickly go through the overall storylines... similar with watching video clips on Youtube... I have a full control over playing videos. These days, I really hate going to theater for watching movies. I cannot stand all the boring parts.”

[P9] “After I got my iPhone, I check my emails every half an hour or so, wherever around the campus. Sometimes, while talking with my friends, if we come up to something unclear, for example movie titles or actor names, I immediately search for the internet. I feel like having any responsibilities for that by having an access to the Internet all the time.”

We also found that individualization and socialization are important aspects of using interactive artifacts that blur the distinction between private and public activities. People can reach others or intentionally detach themselves from others by flexibly adjusting the boundary of personal or social space using interactive artifacts.

[P5] “Sometimes I put my earphones when I want to detach myself from others in public spaces. I don’t really want to listen to music but I can pretend that I am listening to music when I don’t want to talk with others around.”

[P8] “Working with my laptop isolates me from others by focusing on what I am doing even in public spaces. However, ironically the portability of laptop allows me to be around others who may be working on their own things just like me. I can be just around others without active socializing, which I prefer.”

Although this factor of changing behaviors is not about direct connections among artifacts, it is an influential factor that may change overall patterns of human behaviors transforming their perceptions about the reality and thus their expectations for other artifacts around them.

## 6.2 Layers of Artifact Ecology (from EM)

From the ecology map studies, more explicit relations among interactive artifacts were visualized. We found several patterns of those relations– how ecological factors are exemplified in real contexts of use. We define the concept of *layers in an ecology* as different types of relations among artifacts that shape an ecology. Although they are hard to generalize from this initial study, they gave us insights to compare our framework of ecological factors with users’ own description of relationships among artifacts.

### 6.2.1 Purpose of use

Many participants considered relations among artifacts based on their purpose of use, for example, by categorizing some into groups of “work,” “computing,” “gaming,” “entertainment,” “communication,” “graduate studies,” “individual entertainment,” “archive storage,” “freelance-web related work,” etc (Fig 3, 4). Specifically, participant3 grouped laptop, USB driver and digital voice recorder into work-related artifacts, while grouping digital camera and music player into entertainment. Participant 4 also divided artifact groups into laptop, desktop, printer, and external hard driver into work-related computing devices, and television, gaming system, and AV system into entertaining group.

It is interesting that some participants labeled each interactive artifact with very specific purpose of use such as “communication with family” (for a mobile phone) or “communication for team appointment” (for a computer). This shows that although a

number of artifacts support similar tasks, they may provide subtly different emotional or experiential values for very specific purposes of use. In addition, it is noticeable that layers of artifacts based on purposes of use can represent what participants’ main activities are in their everyday life and how those activities are structured through various artifacts.

At the same time, an artifact belongs to multiple layers of different purposes of use. It could be said that the more layers are overlapped for a certain artifact, the more important or essential they are considered representing more connections to users’ activities and to other artifacts. For this reason, computers were often labeled as “core system,” “focal point” or “my heart,” with many connections and layers overlapped in an ecology.

The layer that is grouping some artifacts based on their purpose of use explains how they work together for similar types of tasks. Although they are not always used together at the same time, they are related through ecological factors such as connections through information or functions to support similar user goals.

### 6.2.2 Context of use

Other participants grouped artifacts according to their physical contexts of use- where artifacts are located or where they are mainly used- such as “at home,” “living room media,” “work, lab,” “carry around, surrounding,” and “communication” (Fig 5).

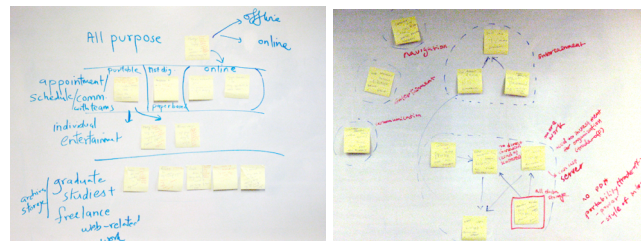


Fig 3 and 4. Highly structured layers of artifacts according to purpose of use (left), layers divided as subgroups according to purpose of use (right)

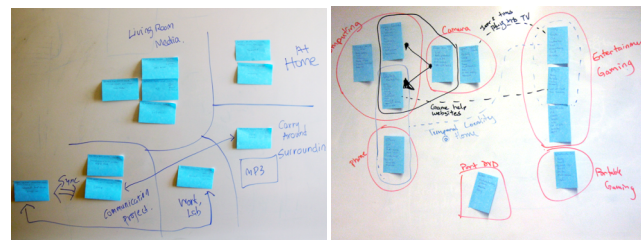


Fig 5 and 6. Layers divided according to physical contexts of use (left), overlapping layers according to multiple connections among artifacts (right)

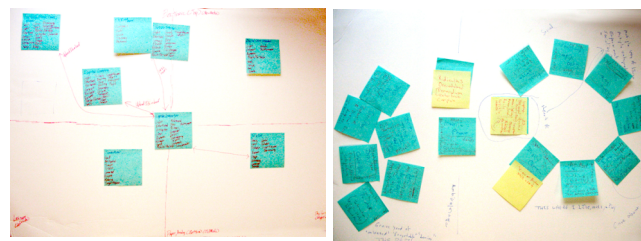


Fig 7 and 8. Artifacts positioned according to different categories of subjective meanings (similar appearance, similar memories, what they care or not, etc.)

Most of artifacts that our participants had mentioned are portable and multi-purpose devices (laptop, digital camera, music player, mobile phone) considering their life styles as graduate students. Due to their portability, some devices are grouped into more than one category of contexts (laptop is used at living room and school, mp3 player is carried around). This tells the importance of considering contextual affordance when designing interactive artifacts as discussed in the earlier section about ecological factors from physical and interactional properties.

It is noticeable that they usually did not use only contextual labels, but also used labels indicating purpose of use such as “communication” or “work.” Participant 9 used several different layers of categorizing artifacts (Fig 6), which show potentials to relate one artifact to another in multiple ways. He mentioned a “temporal locality” as a reason for the relation between his TV and laptop because he usually turns on the TV around when he uses the laptop in the living room. Similarly, Participant 3 mentioned he feels some relation between his laptop and gaming device because occasionally he needs to use the Internet connection for connecting to game help websites. These relations among different artifacts would have never been mentioned in the description of using an individual artifact.

The layer that distinguishes artifacts based on their contexts of use tells that participants are pretty much influenced by physical or temporal contexts when using an artifact. Especially as the contexts could be very dynamic due to the portability of digital artifacts, the support for flexible contextual affordances and seamless connection with other devices around needs to be further explored in terms of physical and interactional properties [37].

### 6.2.3 Subjective meaning

Another layer that we have found from the study is *subjective meaning*, which we named for the value-oriented groupings of artifacts in an ecology. Several participants grouped a few artifacts more closely than others without using any clear labels. However, this relationship may be more implicit than context or purpose of use and is still worthy of our analysis.

Specifically, some people consider the relations among artifacts from their similar appearances or memories. For example, Participant 4 grouped her laptop and digital camera together with a title of “minimal design” (Fig 7). Although she also uses technical data transfer between laptop and other digital devices (such as music players and digital voice recorder), she considered her laptop and digital camera to be more closely related because of their similar appearances. Moreover, she mentioned that those design criteria is one of the most important strategies for her to select new devices to purchase by selecting new artifacts with similar appearance that she already have in her ecology.

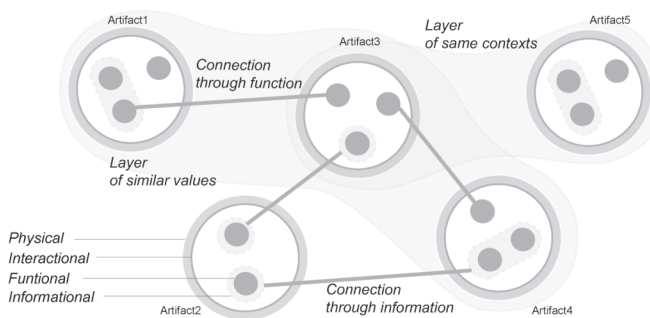


Fig 9. The compositions of artifact ecology

Participant 5 grouped her voice recorder and a music player together because both of them were presented by her father. Although she has some complaints about the features and designs of those devices and wants to purchase new devices, she still keeps using those devices because they remind her of her families and their love.

Participant 8 grouped his artifacts according to his own categories of “I don’t care,” “ambivalence” and “I care about” (Fig 8). Those subjective layers of artifacts represent his emotional feelings to some extent based on the importance or frequency of using different artifacts. He additionally added an annotation to his “I care about” group as “Social, This where I live, work+play” indicating various individual/social activities and thus emotional attachment are engaged with interactive artifacts in that group.

This ecological layer of subjective meaning shows how value criteria for individual artifacts could be applied for the relationships among different artifacts. Further, it also shows how those relationships shape the overall user experiences. Especially, it demonstrates the mutual influence of social norms and personal experiences, which needs to be studied later as an extension of the current framework for personal ecology of artifacts.

## 7. DISCUSSION

We suggest insights and implications for further studies based on the ecological concepts—*ecological factors and layers*—that we defined in the previous section.

### 7.1 Insights from Exploratory Studies

In the findings section, we introduced the concepts of *ecological factors and layers* based on the exploratory study results. *Ecological factors* mostly emerge from the properties or values inherent in a single artifact and make *connections* or *commonalities* among all artifacts building an ecology. *Ecological layer* is the concept that our study suggests might explain how artifacts are related to each other through *ecological factors* in specific environmental or task-related contexts. Additionally, connections and commonalities can be described as fundamental elements that construct an ecology emerging from dynamic interplays among artifact properties and values in various contexts of use (Fig 9). In this section, we will discuss insights from those ecological concepts regarding to the methods (PI and EM) that we employed for exploratory studies.

#### 7.1.1 Conception of ecological factors

Most of the ecological connections were mentioned in relation to functional and informational properties of artifact. Technical “connection” or “isolation” among devices is often critically considered in terms of usefulness of digital artifacts. Also, the role of informational property is becoming more essential as information connects different artifacts by virtually flowing through them. While connections through functional or informational properties were prevalent in the personal inventory studies, they were comparatively less visualized in the ecology map studies. Some participants explained that it might be because they do not significantly realize those technical issues: they are usually seamlessly or automatically done without serious difficulties or they do not remember them in details.

Specific connections or relationships between the physical or interactive properties of a single artifact with other artifacts were rarely articulated. We assumed this is because those properties are more static inherent of an artifact unlike functional or

informational properties that can be easily connected and shared among a number of artifacts. However, we could at least find similar patterns or commonalities from described physical and interactive properties of digital artifacts from this study. For example, increasing concerns on the size of an artifact, such as “portable” or “handy,” were often mentioned as critical physical properties for individual digital devices. Similarly, interactive properties such as “responsive,” “easy” or “complicated,” were often mentioned as main concerns for each device. Although those properties are not directly related to elements of ecologies (connections or layers), they imply considerable design issues—how to materialize complicated informational or functional connections among artifacts with appropriate physical or interactional properties of each artifact.

### 7.1.2 Conception of ecological layers

From the ecology map study, we found how people consider the relationships between artifacts in real use contexts by applying our initial framework of ecological factors. The purpose and physical context of use creates layers of artifacts by grouping relevant artifacts together. It was noticeable that many participants visualized their own way of appropriating digital artifacts through multiple connections and layers. For example, people often grouped some artifacts by selectively using specific features from individual artifacts or creating different connections of artifact features depending on diverse contexts of use. In many cases, those connections were found to be more flexible in artifacts such as display or speaker systems, which support immersive and comfortable environments by connecting compact digital devices with specific features or contents to them.

Due to the multiple layers of an ecology, certain artifacts can work as a hub in a whole system. For example, laptop belongs to more than one group of artifacts, which means multiple connections to other artifacts. It mainly works with home computer or PDA for work-related tasks or checking schedules, but also has a relation with a television in physical and temporal connectivity because a user said that he usually turns on a TV around while working on with his laptop in the living room. Such examples shows possibilities of dynamic interconnections among digital artifacts, which need to be further studied.

### 7.1.3 Ecological values and strategies

The results from exploratory studies can also reveal how people use artifacts and how they have developed their ecologies to some extents. For instance, some people showed very structured hierarchy of artifacts reflecting their strategy of archiving information through different devices (Fig 3). Others divided sub-groups of artifacts considering more local relations according to specific types of tasks or contexts of use (Fig 4). We also found one participant displays a flexible attitude to manage a number of artifacts without organizing any of the information scattered in different devices in an attempt to reduce any efforts to manage them (Fig 8). Those people usually mentioned that they do not need to organize their information in a structured way, because they remember where all of their data (files) are saved. Although their artifact ecologies may seem unorganized to others, they are surely customized under the personal strategies of their owners.

Sometimes, reflective values of artifacts also influence how people develop their ecologies. The social values such as “cheap,” “expensive,” “old,” or “advanced” were considered critical when people change or purchase a new artifact, which would be added

in their current ecologies. Reflective values such as emotional or experiential ones cause a user to feel more attached to some of their artifacts, even though they are not competitive to others in terms of objective functional properties or not suitable to their aesthetic preferences. The value aspects of artifact ecologies need to be more studied for sustainable and meaningful use of artifacts [1]. As digital artifacts become more pervasive and influential surrounding a personal life, it is expected that understanding someone’s artifact ecology would reveal rich personal information including their activities, behaviors, reflective values or identities.

## 7.2 Implications for Further Studies

Although the concept of artifact ecology is yet new and not significantly considered by many people, at least we could find some emerging factors that describe the increasing technical, emotional, or contextual interconnections among artifacts from the exploratory studies. We expect that understanding those ecological factors will support designers to create new artifacts and users to consciously develop personal ecologies while considering the dynamic relationships among artifacts. At the same time, as there is an ever increasing emphasis in HCI research on everyday artifacts that support and improve personal life [2], we believe that refined ecological concepts can help to predict how new artifacts can be integrated into already existing network of artifacts. Based on the results from our exploratory studies, we suggest the following implications to be further investigated.

- Two different methods of our initial exploratory studies, the PI and EM studies, resulted in meaningful findings in our attempt to understand and describe dynamic relations among digital artifacts from an ecological perspective. These studies complement each other in the way they explore multiple dimensions of the use of interactive artifacts with their properties and values. Further investigation with diverse user groups would help to discover various patterns and phenomena of artifact ecologies based on the initial framework of artifact ecology from this study.
- Multi-dimensional properties and values of digital artifacts are expected to help designers and researchers consider and predict the overall influences of digital artifacts in human life. As digital artifacts pervade human life, those considerations would be more critical in terms of sustainable development of human-artifact relationships. Considering the mutual influences between artifacts and users, the perspective of the artifact ecology would provide a more comprehensive design perspective expanding user-centered approaches. Moreover, the current framework of a personal ecology needs to incorporate mutual influences between artifacts and macro-environments in terms of social/cultural ecosystems.
- Ecologies evolve according to individual users’ personal strategies and appropriation of artifacts. Designers and researchers should consider how to support users to develop their personal ecologies flexibly and creatively over time [1, 36]. Beyond technical connections through informational or functional properties, contextual affordance through physical or interactive properties and respect for values need to be critically considered through a systematic and sustainable design approach.

## 8. CONCLUSION

In this study, we conducted exploratory studies to investigate relationships between personal digital artifacts with an assumption that the experience with an interactive artifact cannot be fully understood by itself, but needs to be considered in relation with other artifacts—namely in terms of an artifact ecology. Aiming to

find any implicit or explicit relations within a personal ecology of artifacts, we employed two study approaches – the personal inventory study and the ecology map study. Based on the study results, we introduced the notion of *ecological factors*. They form connections between artifacts or commonalities across the overall artifacts in an ecology, which structures various layers of relationships among artifacts. We expect that the conception of those ecological factors would support different strategies to develop personal ecologies of artifacts for users, designers and researchers in the field of HCI. We will continue to develop this foundational framework through further empirical studies with diverse user groups in our future work.

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