Understanding Lifelike Characteristics in Interactive Product Design

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Abstract

Background Recently, the development of smart products calls for new perspectives on the future role of interactive products around us. One of these perspectives is the analogy of such products with living organisms. Although these visions have been suggested, little has been investigated about how such perspectives can impact practical design.

Methods To guide the design of more emotional and symbiotically interactive products that can be compared to living organisms, we investigated the design characteristics that can trigger impressions of lifelikeness in interactive objects. We collected and analyzed 27 design cases that can be considered to have lifelike characteristics. A case analysis workshop was conducted, composed of sorting of a design case according to its impression of lifelikeness, and an in-depth interview to identify the characteristics of design that affect these impressions. The collected data were analyzed through repetitive affinity diagramming, and the four characteristics of design properties were deduced.

Results Four key characteristics of the design properties of interactive objects were identified: a) similarity in physical properties, b) dynamic behavioral properties, c) independence, and d) userrecognition. The participants tended to perceive an interactive object as more naturally lifelike when its physical propertieshad more similarities with those of living organisms, when its behavioral propertieswere more dynamic, when it was considered to function independently, and when it had the characteristic of recognizing the user.

Conclusions Our work will provide lessons for designing future products and systems using the analogy of living organisms as an emotional experience. We also discussed the design implications of practically utilizing the identified characteristics. There maining issues that need to be discovered, the limitations of the study, and potential future work were also discussed.

Keywords Interactive Design, Lifelike Objects, Analogy with Living Organisms

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1. Introduction

With the development of information and communication technologies, everyday products are becoming more intelligent and connected through the Internet. Although products that assimilate into everyday experience need to provide emotional user experiences, there is a concern that technology-centric products tend to focus on functional aspects and to create negative effects in terms of long-term user experiences (Borgmann, 1984; Strong &Higgs, 2000). Attempts have been made to provide emotional user experiences. Researchers have illustrated such emotional attributes of interactive products as "intimate ubiquitous computing" (Bell, 2003), "affective quality in intelligent agents" (Zhang &Li, 2005), "emotional attachment" (Norman, 2004) "ludic engagement" (Gaver et al., 2004). Nonetheless, visions and exemplars of future interactive products that provide emotional experience are still lacking.

One of the visions of future emotional IT products and systems is that interactive products will behave like living organisms and will sometimes resemble pets. A digital product with artificial intelligence can be compared to a living thing that has its own volition and makes judgments by itself. Many researchers have proposed relevant visions. Norman (2009) stated that the interaction between a future automobile and a driver can be treated as a symbiotic system between a horse and a rider (Norman, 2009, p.47). Row and Nam (2014) suggested a conceptual model of daily Ubicomp products that play a petlike role in terms of providing both pragmatic and emotional experiences. McVeigh-Schultz and his colleagues (2012) proposed a similar vision for the future car, in which passengers can interact with their imagined inner lives. Although these visions have been suggested, little has been investigated in terms of how such perspectives can guide practical design.

We investigate how to design more emotional and symbiotically interactive products and systems using the analogy of the living organism. In particular, we are interested in exploring the possibility of the pet-morphic design approach; using an analogy of pet to designing emotional IT products and systems. Before investigating the concept of the pet-morphic design approach, it is necessary to clear up the blurred concept of lifelike interactive products. Two questions can be asked: What interactive products are felt to be similar to living things, and what characteristics of these products create this impression?

In this paper, we report, through case analysis, on groundbreaking work to identify the design character is tics that trigger lifelike impressions in interactive objects. To identify how the design properties of interactive objects arouse lifelike impressions, we surveyed and analyzed existing design cases through workshops with domain experts. Based on the analysis, we discuss the design implications of how to practically utilize the identified characteristics to design lifelike interactive products. This work will provide the base knowledge that can be used in various design activities, focusing on pet-morphism in the future.

2. Related Works

Related works can be divided into the oretical research on how to support emotional user experiences with IT products and systems and practical research studies related to applying the analogy of a living organism(such as a pet)in designing interactive systems.

2. 1. Theoretical research on how to support emotional user experiences with IT products and systems

Researchers have explored design approaches to enhance products' emotional value. One of these approaches is to maximize aesthetic appreciation by adjusting the design attributes. Users' emotional conditions are influenced when visual design attributes, such as form, color, and material, are morphed (Desmet, 2001, 2005). As IT products embody dynamic design attributes such as interaction, kinetic movement, or gesture-driven features, researchers have investigated such attributes. Lim et al. (2007) articulated the design attributes that pertain to users' emotional experiences, focusing on interactive aspects. Many studies have focused on physical movement and its effect on different emotional states (Singh, 2013;Hashim et al., 2011; Jung, 2013; Lee et al., 2007; Uekita, 2000). These researchers explored how the dynamic attributes of products, including rhythm, tempo, sequence, and directions, can affect a user's mental state.

There have also been studies on how to enhance emotional quality through users' individual characteristics. These include making meaningful designs with a personal history of use (Moon et al., 2015), reflecting on oneself and the past through slow interaction (Grosse-Heringet al., 2013), and embodying users' personalities or narratives (Odom et al., 2009).

Another approach relating to emotional interaction of intelligent IT products and systems is to utilize an artificially intelligent agent. Anthropomorphic or lifelike agents make users interact with IT products as if they were living things. Robotic companions are typical lifelike agents, and works in this field have implied that interactions, expressed through living metaphors, can help to enhance product intimacy and empathic relationships (Martiet al., 2005). Although numerous studies have tried to development more lifelike and affective agents through human-gaze sensors and emotional feedback (Nass & Moon, 2000; Picard, 2000), the focus of these studies still remains at the level of technological improvement as a way to reproduce a real creature, for example, by implementing a humanlike cognition model (Nass & Moon, 2000; Cassell, 2001) or by establishing an elaborate moving mechanism (Marti& Schmandt, 2005; Breazeal, 2003).

Some recent works have partially answered how to enhance lifelike qualities in IT products and systems and has identified what would be a more natural and lifelike expression for various devices. For example, Osawa and Imai (2013) proposed humanlike eyes and arms as triggers to make ordinary artifacts more like agents. Funakoshi et al. (2008) glimpsed the potentiality of humanlike nonverbal communication in the subtle expressions of robots, such as blinking lights or beeping. sounds. Yamada's (2013) research team showed that the motion-based, subtle interactions of robots can be useful for representing a robot's feeling of confidence. However, there has been a lack of exploration into product attributes associated with emotional and delightful feelings, and even less consideration has been given to this from a design perspective.

2. 2. Practical research studies that have applied the analogy of the living organism, including pets and animals

In the HCI and design fields, attempts have been made to apply zoomorphic or animistic features, in terms of appearance, behavioral patterns, or even biological characteristics, to interactive products and systems. For instance, researchers and designers have applied lifelike kinetic movements (Kim, 2012; Probst et al., 2011; Ueki, 2007), narratives of living things (Odom &Pierce, 2009; McVeigh-Schultz et al., 2012; Kim & Nam, 2009), or characters of exotic pets (Ljungblad & Holmquist, 2007Jacobsson et al., 2008) into the design process. They mainly expected to take advantage of the ingenious, delightful, and emotional aspects of various animals (Odom &Pierce, 2009; McVeigh-Schultz et al., 2012; Jacobss on et al., 2008; Helmes et al., 2011). The ways in which the analogy of the living organism is applied to products can be classified into five functional aspects: for notification, for amusement, for decoration, to use as a system analogy, and for social interaction.

2. 2. 1. Notification

Many design cases use lifelike, active movements to represent the status of an objector to deliver messages. For example, a product called the Impatient Toaster rings loudly as if it is in a bad temper when the bread is well done (Burneleit et al., 2009). Another item, called Move-It Notes, informs people of the time written on a sticky note through wormlike bending behavior (Probst et al., 2011).

2. 2. 2. Amusement

Some design cases were inspired by living things to enhance the playful and delightful aspects of interactive products. The products (In)Security Camera (Zoontjens, 2010), Friendly Vending (Baggermans, 2009), and Rudiment #3 (Helmes et al., 2011) demonstrate interactions inspired by an animal’s ability to recognize humans. Iron Bike is an interactive bike that sounds like riding a horse (Landin, 2002). Knoby is a doglike doorknob with an unlock gesture that was designed using the analogy of a pet owner’s gesture of touching a pet dog’s chin (Kim et al., 2012).

2. 2. 3. Decoration

Some cases have ornamentally borrowed animal like appearance or motion for their physical forms. Gina blinks its headlights like an animal’s eyes and organically moves its cover for an aesthetic reason (BMW, 2008). Sen.se.Mother and Nabaztaq are both Internet-of-Things (IoT) devices that have creature-inspired, rounded shapes—those of a rabbit and a Matryoshka doll, respectively. They also behave like animals (e.g., in their ear movements) to give a feeling of friendliness.

2. 2. 4. System analogy

Several systems have been designed with functional metaphors of living organisms. They were given the physiological structure of living things or the structure of a biological ecosystem (McVeigh-Schultz et al., 2012; Van Allen et al., 2013). Biometric Daemon is an example of a product that functions like a pet in terms of its interactions, such as recognizing a user and requiring a user’s care (Briggs &Olivier, 2008).

Van Allen's research team (2013) explored the concept of heterogeneous multiplicity, that offers unique opportunities for our ecosystem, a model for a design ideation system that offers unique opportunities to stimulate human creativity (Van Allen et al., 2013). Several researchers have addressed the usefulness of the living thing analogy for systems design in terms of intuitive understanding or perceived believability (Hays-Roth et al., 1998; Sara et al., 2005).

2.2.5. Social interaction

Socially interactive objects, including robotic pets, have been designed to simulate animal pets, to provide cordial experiences and to commune with users (Breazeal, 2003; Fong et al., 2003). Aibo and Paro are representative cases, imitating the emotional interactions of real dogs and seals, respectively, through hugging actions and fluffy skin (Fujita, 2001; Wada &Shibata, 2007). Empirical studies have shown that users can form emotional attachments to and feel comforted by artificial pets. For example, Aibos had an influence in treating users' mental health problems (Friedman et al., 2003). These cases can be seen as attempts to make alternative pets imitate real pets.

To summarize, previous research studies have increasingly attempted to utilize lifelike characteristics in emerging IT products and systems design not only with a view to adding emotional value but also for useful purposes. However, research studies have not focused much on the question of what products are felt to be more natural in terms of their likeness to living things and what attributes can create the impression of being lifelike or being petlike. Previous work has tended to directly apply fragmented characteristics of animals, and there has been a lack of theoretical consideration. Even design outcomes derived from an explorative process have remained in the initial stages of design exploration due to limited empirical evaluation. Another limitation of the literature is that no comprehensive studies have included various existing cases to create a holistic perspective.

3. Case Analysis Study

While some objects look like inanimate objects, others look like living pets that interact with us. In this basic research, to find a method for designing lifelike interactive products, we attempt to identify the key characteristics that cause people to regard a thing like a living organism. We collected and analyzed existing interactive design cases that have lifelike characteristics. We intended to identify the characteristics of design properties for each object that provides a lifelike impression. The study involved collecting design cases and conducting workshops to extract the key characteristics.

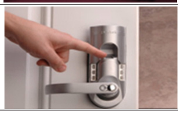
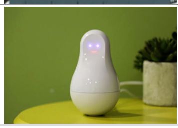
3. 1. Design case collection

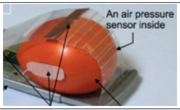
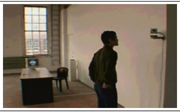
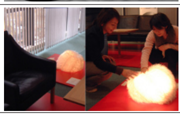
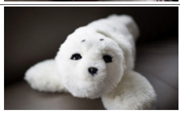
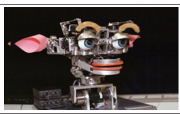
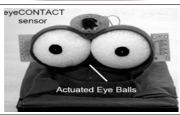
We collected existing design cases of interactive objects that are considered to have lifelike characteristics. For the existing interactive artifacts, we looked for commercial products, conceptual designs, and media artwork using a Web search (e.g., design museum sites, design blogs, and online shops). We also looked into research cases from HCI-related journals and conferences from the past ten years.

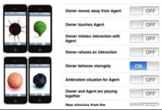
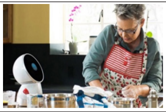
After eliminating analog products that only imitated animals' appearance without an interactive aspect, we initially selected 107 cases (86 tangible objects and 21 media artworks) and then narrowed these down to 27 cases (Table 1). The criteria were the object's resemblance to everyday digital products and whether it had physical form. The rationale behind was that we set our application domain as everyday interactive products, which major form are physical materials rather than virtual presence. We expected that understanding what characteristics or elements of physical objects can affect the feeling of lifelikeness might be more applicable to future design activities.

These 27 designs included IoT devices, daily products, media artworks (e.g,(In)Security Camera and Friendly Vending), research prototypes (e.g.,The ThriftyFaucet), and future-concept products (e.g, Gina and Jibo). We produced explanatory materials and archived related videos, images, and texts to quickly and thoroughly explain each object.

Table 1 Description of the Final 27 Design Cases

no.	Name	Representative image	Functional description of the object	Object type
1	Impatient Toaster		A toaster that announces that food is ready with vibration and sound	Research prototype
2	Move-It Notes		Interactive notes that announce the user's schedule with a bending motion	Research prototype
3	The Thrifty Faucet		A faucet that bends as if it is seeking something to guide users to water consumption	Research prototype
4	Gina		A car that blinks its headlights and spreads its doors organically	Design concept
5	Talkative Cushion		A sound recorder that converts voices into ludicrous sounds	Research prototype
6	Biometric Daemons		An authentication system gradually strengthening its security over time	Research prototype
7	Friendly Vending		A vending machine that turns its cans toward pedestrians	Research prototype
8	Sen.se Mother		An IoT device to helpto manage in the user's daily life	Commercial product
9	Nabaztaq		A rabbit-shaped ambient device that represents Facebook feeds or weather information	Commercial product

10	The Proverbial Wallet		A wallet that gives haptic feedback to reflect the user's account balance and previous transactions	Research prototype
11	Inflatable Mouse		A mouse device that can be inflated or squeezed as I/O method	Research prototype
12	(In)Security Camera		A camera that moves against users to avoid people	Media art
13	Knoby		A petlike door knobopened with a strokinggesture and greets a user	Research prototype
14	Glowbots		Wheeled robots that interact with each other and create an attractive pattern on it	Research prototype
15	Iron Bike		A bike that sounds like a horse galloping when being ridden	Research prototype
16	Tabby		An air conditioner that flickers and blows to mimic breathing according to the air conditions	Research prototype
17	Emotional Palpus		An attachable device that moves according to emotions	Research prototype
18	Nikko Dama		A toy that blinks its eyes occasionally	Commercial product
19	Paro		A seal-shaped therapeutic pet robot	Commercial product
20	Kismet		A face like robot that uses human emotion	Research prototype
21	The Vein of Life		A vein that becomes red when exposed to sunlight	Commercial product
22	Eye-Phone		A smartph one that makes eye contact with the user	Research prototype
23	Clocky		An alarm clock that rolls around and makes a fuss to wake the user up	Commercial product
24	Koi Pond		A set of interactive cups and coasters that create a koi image when they meet	Commercial product

25	Koi Pond		A set of interactive cups and coasters that create a koi image when they meet	Commercial product
26	Potpet		A phone that indicates its functional state in an abstract graphic	Research prototype
27	Jibo		A social robot for the home	Commercial product

3. 2. Workshop for extracting the key characteristics

We carried out a workshop composed of card-sorting and an in-depth interview to identify which characteristics of design properties played a significant role in the commonly shared impressions of an object being lifelike. Fifteen domain experts comprising graduate students with HCI-related majors (e.g., industrial design, robotic engineering, and computer science) were recruited due to their deep knowledge of the interactive objects' properties, which would enable them to explain the designers' viewpoints.

3. 2. 1. Workshop Procedure

We provided the participants with the aforementioned explanation materials and representative cards for the 27 products (Figure 1). Participants were required to classify cards into three or five levels based on the strength of their impressions of the products' life likeness. Afterwards, they chose three cards from different level for a comparison in the in-depth interview (i.e., the triading method; Hanington &Martin, 2012). Participants explained which characteristics of design properties made the products feel more lifelike.

Figure1 Card-sorting workshop (left)and concept description card (right)

They were required to make assumptions about the situations in which they would be using the products because they had to evaluate without real objects. When an object was not considered to be lifelike, we asked the users how the design could be improved. Through this, we found that our study was not limited to finding characteristics from the selected 27 cases and that more explorations could be performed. The workshops lasted about 40 minutes per participant.

3. 2. 2. Data collection and analysis

The whole interview process was recorded and transcribed (11 hours and 20 minutes in all). We divided the script into several sentences and grouped each sentences based on the similarity of their design properties. For instance, Participant 4 (P4) stated that“(In)Security camera(No. 12) felt more alive than Nikko Dama(No. 18) because it was more intelligent in acknowledging me as an owner.”Such statements guided us to interpret that qualities such as a high level of intelligence and the ability to distinguish a user or react to the user’s status reinforced impressions of lifelikeness. In the next stage, each term that was supposed to influence impressions of life likeness(such as distinguishing the user, reacting to the user’s status, mirroring the user’s behavior, and caring for the user) were grouped together as the upper level of features under the category “recognizing the user.” The repetitive process of affinity diagramming was conducted, and the four characteristics of design properties were finally deduced.

4. Findings: Four Characteristics Triggering the Lifelikeness of an Interactive Object

Through the above analysis, we identified four characteristics that influenced users’ impressions of lifelikeness: i) similarity of physical properties, ii) dynamic behavioral properties, iii) independence, and iv) user recognition.

4. 1. Similarity in physical properties

The first characteristic relates to appearance, an external property of interactive products. We apprehended how the products’ expressional dimensions (2D or 3D), materials, physical forms, colors, and component arrangements influenced their perceived lifelikeness. First, participants regarded objects as more lifelike if the objects had a part that reminded users of an animal’s body (such as a face, a palpus, an ear, or fur). In P5’s words, “Because where the buttons are placed causes Clocky(No. 23)to seem like it has a face.” Other participants mentioned the tail like protrusion of Knoby(No. 13) and the furry textures of Paro(No. 19) and Tabby(No. 16)as making these objects more naturally lifelike.

In addition, participants felt the objects were more lifelike if their appearances were closer to those of living organisms. For example, more organic, rounded shapes were found to be more lifelike than geometric shapes, and three-dimensional shapes were more lifelike than flat shapes. P10 said that the Impatient Toaster (No. 1) could be more lifelike when its facial expression was not graphical. In P10’s words, “The object should seem more realistic to make it more lifelike”. 3D expression is better than flat animation.” Interestingly, many participants responded that a light color (almost white) and a round shape are well-matched to lifelike objects. In our 27 cases, Nabaztaq(No. 9), Jibo(No. 27), and Sen.se.Mother(No. 8) had those characteristics and were preferred. Meanwhile, Potpet(No. 25), Iron Bike(No. 15), and(In)Security Camera(No. 12), which have machinery, a box shape, or wheels, were seen as less lifelike. Products that did not have any physical similarities were not perceived as lifelike objects.

P7 stated that “Biometric Daemons (No. 6) and Emotional Smartphone(No. 26) applied the analogy of a living creature in a conceptual way and without any explicit expressions. I understand the pet metaphors that they used, but the products are just smart computer systems—no more and no less.”

Unexpectedly, objects that closely resembled real creatures tended to not be considered very lifelike. One of the reasons for this could be that people naturally expected that, based on their appearance, these objects might have unconstrained functions and high intelligence (like a real creature), but the product could not meet that expectation.

4. 2. Dynamic behavioral properties

The second characteristic relates to the behavioral properties of interactive products. Whether the product's movement is dynamic or clear enough influenced the user's impressions on lifelikeness.

Mostly, if an object moved in a livelier way, more participants felt that it was lifelike. For example, Inflatable Mouse (No. 11) and The Proverbial Wallet (No. 10) only vibrate or inflate and are otherwise static, so these were regarded as less lifelike than Move–It Notes (No. 2) or The Thrifty Faucet (No. 3), which move in specific directions. Potpet (No. 25) and Clocky (No. 23) move in a2D plane, and they gave more lifelike impressions. In P7’s words; “I think Koi Pond (No. 24) is an absolutely inanimate product. It might have been more lifelike if it had been developed to bleed or have a fluttering vein.” Participants tent to feel that dynamic and prominent movements were closer to the nature of real creatures. In P8’s words, “Even for plants, a puckering mimosa against my touch looks more alive than still plants. For that reason, Biometric Daemons (No. 6) changed steadily and gradually, making them feel not very lifelike.”

Adding to the liveliness of a behavioral pattern, another factor was whether an object’s response was frequent enough or occurred immediately enough to give the impression that the object was lifelike. For example, Gina (No. 4) used organic motion, gently turning its headlight to resemble an animal’s opening eyes. Regarding Gina (No. 4), P2 stated that it felt like a static car because the blinking motion only occurred when the light was on, not continuously. He added "That moment there maybe a feeling of living things temporarily, however the most of the time I ride a car, I won’t feel that impression anymore. It's too momentarily.

4. 3. Independence

The third characteristic relates to whether users regard the object as an independent agent. Independent agents are self-determinable and are seen as having free will and intelligence, and they can move autonomously. We apprehended that users tend to see an object as lifelike when it operates in an independent way.

Mainly, participants thought that the lifelikeness of the object was higher when an interactive object showed unexpected feedback based on a participant's intention. The best examples are The Proverbial Wallet (No. 10), which prevents its owner from wasting money,(In)Security Camera (No. 12), which avoids people’s eyes by turning its head against the audience's gaze, and The Thrifty Faucet (No. 3), which changes the direction of the faucet to disturb users in washing their hands. Since these products work against the users’ preconceptions, they were considered to have mental faculties.

In addition, participants also thought objects were more lifelike when they seemed to run automatically without any operation. For instance, Glowbots (No. 14)were frequently mentioned as highly lifelike objects because they interacted among themselves without users' assistance. Participants generally compared them to insects which gather in swarms. On the contrary, KoiPond (No. 24) was not regarded as lifelike because it only changed color when users placed a cup in a certain area. Though both Iron Bike (No. 15) and Potpet(No. 25) have wheels and mobility, users perceived them as having differing levels of lifelikeness due to their differing degrees of automaticity. Potpet (No. 25) was considered to be a lifelike object (reminiscent of a dog)as it kept a flowerpot moist; however, Iron Bike (No. 15) was considered to be a mere transportation device because it depended on a user's control. In P12's words about Iron Bike (No. 15) and Gina (No. 4):"Their movements are the same as those of bicycles or cars. Because the principle of mechanical motion "is obvious, these objects didn't seem new and couldn't draw my interest. They are machines controlled by humans mimicking animal sound and movement." P9 added, "Despite organic movement, I feel that Gina (No. 4) is a machine because it only reacts when users switch it on or off."

4. 4. User recognition

User-recognizing characteristics are some of the key characteristics that enhance interactive products' life likeness. This fourth characteristic refers to how well the interactive object portrays the capability of recognizing a user. The capability of user recognition encompasses sensing the user's personal biological data, creating activity logs, providing care services, and simply distinguishing between a user and strangers. This characteristic relates to whether an object provides functions relevant to the user's identity and personal information. For example, Sen.se.

Mother (No. 8) was usually considered more lifelike than Nabaztag (No. 9) because Sen. se.Mother (No. 8) has functions that reflect the user's status and help users to manage a regular life, but Nabaztag (No. 9) simply functions as a weather notification system. Nikko Dama (No. 18) and Friendly Vending (No. 7)both use looking behavior, but users rated their lifelikeness differently due to their user-recognizing characteristics. Many participants evaluated Friendly Vending(No. 7)as more lifelike because Nikko Dama (No. 18) randomly blinks, but Friendly Vending(No. 7) turns its body toward the user. Regarding Tabby (No. 16), P7 noted, "It resembles a pet because it is covered with fluffy fur, but if it had been more closely mapped to the user's daily status or breathing pattern instead of focusing on air filtering, it would have been more petlike."

5. Discussion

The results of the workshop reveal when an interactive object can be perceived as being naturally lifelike. This study also raised several issues, such as which characteristics are arguable and how best to apply each characteristic to design. We also highlight implications for future design here before discussing this study's limitations and future work.

5. 1. Implications for the Use of the Attributes for Petlike Object Design

The study results illustrate that there are several things to consider when applying lifelike characteristics to interactive product design. To enhance the lifelike impression of an interactive object, a designer can consider a combination of four characteristics.

Physical characteristics are simple to adopt. Designers can merely add physical parts that resemble those of a living organism, such as levers signifying arms, cables that look like mouse tails, or antennas reminiscent of rabbit ears. Designers can also try to rearrange products' components to express animal like faces. Let us imagine we are designing a lifelike smart toy car for preschool children to provide them with an emotional and delightful experience. We can start our toy car design by attaching to an ordinary toy car an antenna that looks like a wagging animal tail and side mirrors that move like animals' ears. To give a facial image, information from the dashboard system can be changed to the form of a symbolic face (Figure 2).

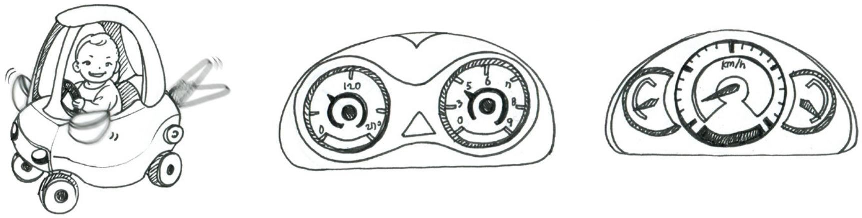


Figure 2 Toy car design with tail like antenna and earlike side mirror (left) and dashboard design with a symbolic face and without a facial image(right)

Regarding behavioral characteristics, the behavioral patterns of an interactive object must be designed to be lively enough to be eye-catching. This can be achieved by regulating the object's speed or moving range.

For more natural applications, designers can associate the behavioral patterns of the objects with their functions and roles. The Potpet (No. 25) is one example. Potpet (No. 25) moves toward sunlight, which helps its flowerpot to bask in the sunshine. When designing a lifelike electric bike, a gauge indicating the amount of gas remaining can be redesigned. The gas gauge of an ordinary bike moves up along with the amount of gas when a user is refueling the bike. What if it rose more vigorously, as if in the prime of its strength (Figure 3)?

Figure 3 A Gas gauge rise vigorously

One way to apply independent characteristics to interactive products is to design the product to gradually disclose hidden functions and unexpected interactions as it is used. If this does not spoil usability, such products can occasionally refuse the user's execution. For example, a lifelike children's bike can shake its handlebars and standing its fender board upright when the weather is unfavorable (Figure 4).

Figure 4 A children's bike refusing to load when the weather is unfavorable

Regarding user-recognizing characteristics, designers can increase the impression of lifelikeness by reflecting users' own characteristics in the interactive product design, including the history of use, biological data, daily activity logs, and appearance-related peculiarities. Otherwise, a product can simply differentiate its owner from other people and provide exclusive services or functions to the owner.

The interview results indicated that such recognizing interactions reminded participants of pets' behavior, such as being delighted to see their masters. Inspired by the pet-master relationship, designers may attempt to create an intermediate stage for the period of getting accustomed to a product's usage, just like people get familiar with their pets. When designing a lifelike children's bike, designers can make the bike progressively recognize its user rather than have it do so all at once. For implementation, vision-sensing technology enables the product to detect the presence of its owner, enhancing its security (Figure 5).

Figure 5 A children's bike recognizing its owner (greeting interaction)

5. 2. Other characteristics that may enhance lifelikeness

We admit that the impression of lifelikeness was also affected by the participants' individual differences, such as their personal experiences, memories, values, and thoughts. For example, there was a disagreement over whether the robotic face of Kismet (No. 20) was lifelike. While some participants regarded the typical robotic face as a lifelike face, others considered it to be machinelike. We supposed that the images in the human mind that prompt lifelike feelings are not the same and that there were differences from person to person. Meanwhile, in response to the question, "Why do you think that the product is so lifelike?", several participants mentioned that the product made them recall their acquaintances, close friends, or family members. For example, Impatient Toaster (No. 1) evoked in some users the image of their mothers waking them up every morning, and Talkative Cushion (No. 5) reminded them of chatter between friends.

It is difficult to generalize, however, and Desmet (2001) and Govers and Mugge (2004) have already dealt with personal experience as an important factor in product emotion. They argued that a product (which they call a stimulus) is perceived differently depending on the user's personal goals, standards, and attitudes. Our study is focused on the design properties that are easily adjustable, however, further study about the more complex aspects of these characteristics can be studied in the future.

5. 3. Toward petlike products and systems

In the future, design characteristics for lifelike objects may be applied through the analogy of pets. Can lifelike objects be petlike objects, and what issues need to be addressed to establish a pet-morphic design methodology? Petlikeness can be a subcategory of lifelikeness, and petlike products may have other characteristics beyond those of normal lifelike products. Although it is difficult to verify the concept of petlike products and systems, we can imagine that future interactive devices will intelligently manage users' needs and self-regulate using various sensors and IoT technologies. In addition, we speculate that these devices will be friendly and lovable, with lifelike features. Petlike artificial intelligence may bring up an issue about how sophisticated the intelligence must be before it is well-associated with that of a pet.

One opportunity is the emergence of smart-but-dumb products, which are intelligent enough to sense users and environmental data but which are covered with petlike dumb characteristics to make them felt friendly and not technologically advanced. Independence and user-recognizing characteristics can be mainly considered as ways to control the intelligence level of petlike products.

5. 4. Limitations and future work

We intended to cover diverse cases as much as possible, and expected users to comprehensively deal with various enough cases within short session. One of the limitations from this is that participants could not experience the real products and they had to rely on the imaginary feeling led by explanatory materials such as video clips. Though we asked them to imagine specifically about what if they used the products, this might result in overlooking some aspects relating to a real usage situation. For example, emotional bonding through a long term relationship with a product can affect on a user's perception of a product's lifelikeness (Friedman et al., 2003). The second issue is validity of the characteristics. It could be argued that the identified four key characteristics are quite reasonable in terms of data collecting and analysis procedure. We asked the participants to transform the concept in to new ideas to find out more characteristics which might not have been appeared in the cases. We iteratively repeated the interviews to establish enough amounts of data, until there are not new answers. Nevertheless, we understand that that qualitative analysis methods used here can have rooms for improvement. For future work, an empirical study for evaluating their validity should be followed. In this validating study, each characteristic can be developed on a more elaborate level.

To utilize these characteristics in design practice, design guidelines for applying each characteristic can be also studied for future works. For example, we can research the optimum levels of lifelike expressions, such as how lively movements should be or how long animated behaviors should last.

6. Conclusion

Starting with the vision that future interactive products and systems can be designed with an analogy of living creatures or smart pets, we identified which existing interactive design cases provided the strongest impressions of lifelikeness and identified the key characteristics of product properties that triggered those impressions. These key characteristics include similarity in physical properties, dynamic behavioral properties, independence, and user recognition.

Each example referred to in the workshop process and the discussion about design exploration will provide lessons for applying these characteristics to emotional and interactive product design.

This study also proposes a novel perspective on pet-morphism for intelligent products and systems that are already assimilating with our daily lives. The results of this study will have practical implications for advanced emotionally interactive products and systems and for deploying pet-morphic design methods in the future.

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