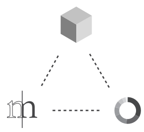

EXPERIENTIAL AUGMENTATION

REPRESENTING INVISIBLE DIGITAL PROCESSES WITH INTUITIVE PHYSICAL PROPERTIES

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Thesis, Masters of Design
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WITH INTUITIVE PHYSICAL PROPERTIES

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ABSTRACT

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As we move toward a world of ubiquitous computing, it is important to think about how computing should communicate with us when it is distributed in our environment. Designers of ubiquitous computing will meet two challenges. The first is the challenge of invisibility, technology will have to find new ways to communicate with us without the advantage of smartphone or desktop screens. The second challenge is that of calmness, ubiquitous technology must communicate in a way that doesn't overwhelm the user.

This thesis shows that one possible way to meet the two challenges is for computing to communicate in a way similar to the language of objects in our environment. Our environment communicates with a qualitative and experiential language. Thus, this thesis studies the simulation of experiential physical phenomena in augmented reality, to give representation to invisible processes in objects.

To explore this direction of augmented reality, a body of twenty one experiments were created and tested with participants. Participant interpretations of experiential augmentations were then gathered and distilled into a three-pointed model for categorization. The study ends with a series of recommendations for designers interested in pursuing similar types of object augmentation.

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Chapter 1
FRAMING EXPERIENTIAL AUGMENTATION

USB drive float: This is an example experiential augmentation, where the illusion of weightlessness is simulated through the alteration of an object's shadow.

INTRODUCTION

The following sections review the motivations and literature behind the framing of experiential augmentation. The work in this thesis is more concerned about the way augmented reality (AR) should be used, rather than the technical aspects of execution. As a result, literature reviewed ranges from texts of human computer interaction, to communication design, psychology and linguistics.

Ubiquitous computing

The framing begins by introducing ubiquitous computing as the next phase of computing, and explaining the challenges we face in the design of technology in a ubiquitous context. The first challenge is that of invisibility. Most technological processes are invisible, and this thesis argues that we need a way to understand the technology embedded around us. The second is the challenge of calmness, the thesis argues that technologies must communicate with us in a way that is not overwhelming.

The way the world communicates

The next section suggests that the challenges of invisibility and calmness can be solved by having computers communicate with us in a way that is more consistent with objects in our environment. This method of communication is called indexical visualization (Offenhuber 288). Experiential augmentation uses indexical visualizations to augment objects, allowing us to imagine their invisible processes.

Visions of augmented reality

This section introduces augmented reality as one of the tools that can help us understand embedded technology in our environment. However when looking at the way technology companies and popular culture are imagining the future of augmented reality, we see that they strive to project the virtual world onto the real, avoiding both the challenges of invisibility and calmness.

The building blocks of experiential augmentation

Experiential augmentation is a version of augmented reality that tackles both challenges of invisibility and calmness. To construct experiential augmentations, a wide range of foundational research is tapped, ranging from schema theory in psychology, and data visualization fundamentals, to the way metaphors are used in linguistics.

UBIQUITOUS COMPUTING

An introduction of computing as we currently see it, how it will evolve, and the two challenges we face as it evolves.

The future of computing

In 1991 Mark Weiser wrote his seminal work "The Computer for the 21st Century", predicting the coming of ubiquitous computing, when computers will be able to "weave themselves into the fabric of everyday life until they are indistinguishable from it" ("The Computer" 1).

Today, much of the technology we use is centralized in desktop, laptop, and mobile computing devices. However we are seeing signs of ubiquitous computing, within various smart appliances (thermostats, light bulbs, vacuum cleaners), and voice activated smart assistants that are available for consumer purchase. The evolution of ubiquitous computing will bring new design challenges that are outlined in this section.

The challenge of invisibility

If computing is embedded in our environments, does that mean the world will be automated in such a way that we forget computing exists at all? Designer Timo Arnall explains the problem with this approach, saying that "contemporary visions of technological development often focus on invisibility and 'seamlessness' in interface technologies, while the methods of building knowledge about designing with these technologies or issues of agency and control over these interfaces are overlooked" ("Exploring Immaterials" 101). According to Arnall, our ability to build, and even use technologies depend on a clear understanding of how the technology works. The more technology is embedded in our everyday environment, the more important it is for these technologies to be visible. Otherwise, we risk a lack of understanding that "leads to uncertainty, unhelpful mythology or folk-theories.... That hinders our ability to design or use technical systems, and clouds the critique of technological developments" ("Exploring Immaterials" 101). The more seamlessly technology is embedded in our environment, the greater the chance we will overlook and misunderstand them. Arnall's solution to this problem is to find ways to visualize the invisible processes in computing. His own work for example, includes using long exposure light photography to visualize radio frequency identification (RFID) fields.

The challenge of calmness

Arnall explains that if we strive to design technology that is able to make itself visible, a second challenge arises—that of calmness. The centralised computing we have today assumes our full attention, an assumption that is at times life threatening. Texting, for example, takes away a person's ability to drive safely. Weiser observes that "our common metaphors for computer interaction lead us away from the invisible tool, and towards making the tool the center of attention" ("The World" 1). However, if technology is embedded in our surroundings, and every piece communicates in a way that assumes our full attention, we will be overwhelmed by information. In a world of ubiquitous computing, our computers need to be able to "move easily from the periphery of our attention, to the center, and back" (Weiser, "The Coming" 3). Weiser calls this ability "calmness".

It is important to note here that the invisibility Arnall is fighting against, and the invisibility Weiser strives for, are different things. Arnall describes invisibility as something that obscures understanding of technology. However, Weiser views invisibility as something that arises from understanding. Weiser states that "whenever people learn something sufficiently well, they cease to be aware of it" ("The Computer" 1). In Weiser's definition, a calm and invisible tool is one that we understand so well, that we do not need to think about it when using it. To avoid confusion, from here on when referring to the "challenge of invisibility", it is Arnall's version of function obscuring invisibility that is being referenced.

Exploring language as a solution

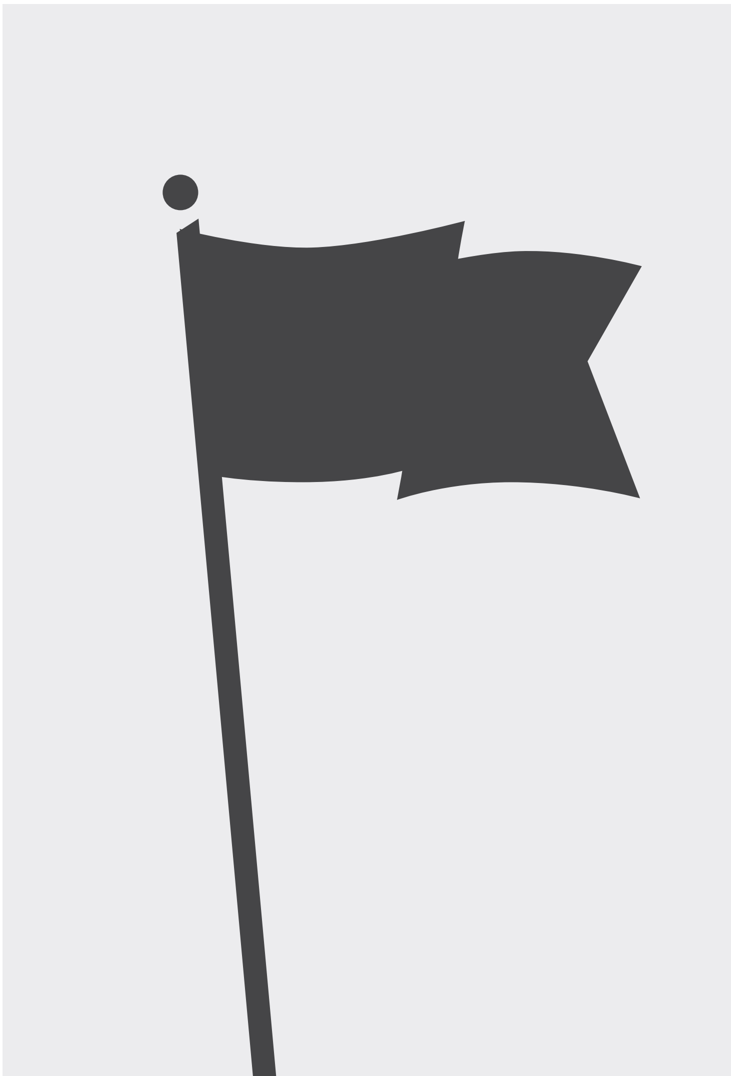
Since the challenge of invisibility and the challenge of calmness arise from the way technology communicates with us, this thesis hypothesizes that modifying the language of technology is a possible solution. Weiser explains that current computer "cannot truly make computing an integral, invisible part of people's lives" ("The Computer" 1), because "the computer... remains largely in a world of its own. It is approachable only through complex jargon that has nothing to do with the tasks for which people use computers" ("The Computer" 1). This thesis aims to take Weiser's thoughts a step further, in saying that the jargon used by computing is out of place and attention hungry when used with ubiquitous technology, because it is so different from the language things in the physical world use to communicate with us. Thus, this study focuses on understanding what the language of the physical world is, and how it can be applied to ubiquitous computing.

THE WAY THE WORLD COMMUNICATES

An introduction of the language of the physical world and its application in visualization.

The intuitive language of the world is qualitative and experiential. For example, we can understand the strength of wind outside by watching how violently a flag flaps on a pole. We understand what gift we are receiving for Christmas by shaking the box to hear what is inside. In "The Coming Age of Calm Technology", Weiser himself cites an example of qualitative and experiential language as an example of calm technology. He describes the qualitative sound of an engine as a representation of a car's health that we are able to filter out or pay attention to.

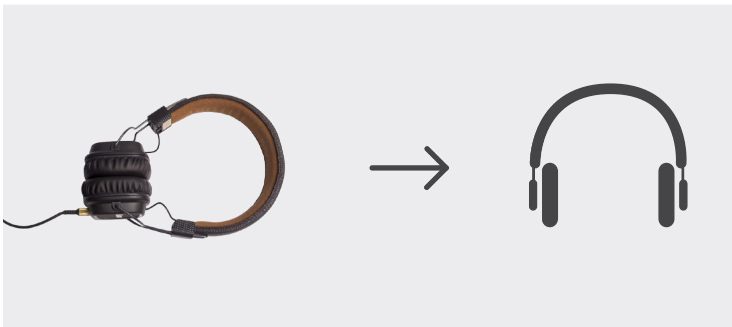
Flag: The way a flag visualizes the strength of the wind is an example of the experiential and qualitative language of the physical world.



The use of qualitative and experiential visualization in this thesis aligns to what Dietmar Offenhuber and Orkan Telhan describe as indexical visualization. Indices belong to one of three types of signs (symbols, icons, indices):

1. Symbol
Symbols have no direct relationship to the underlying data and have to be memorized. Numbers are an example of a symbol.

2. Icon
Icons resemble objects they stand for and can be decoded through appearance.



3. Index
Indexes have a causal connection to an object or underlying data. For example, the wear on a shoe is an indexical visualization of how far someone has walked.

Conventional computing systems make heavy use of symbols and icons, but indexical visualization is rarer. It is this third category that designers are beginning to turn to in the design of various ubiquitous technologies. Offenhuber states that "Concepts such as Calm Technology and Ambient Displays are directly inspired by the indexical nature of analog instruments and the human capacity to constantly process a multitude of environmental cues "without too much effort or with the background of attention" (293). This suggests that qualitative and experiential displays are a possible solution to the challenge of calmness in ubiquitous computing, and a key to building interfaces that do not assume our constant full attention.

Where this thesis would like to apply indexical visualization to

Indexical visualizations are used in tangible interfaces and ambient displays. This thesis however, uses indexical or experiential visualization to provide an alternative to the way augmented reality is being imagined, especially in the context of augmenting objects which have physical and invisible components. Experiential augmentation is the use of augmented reality, in a calm way, to help us understand the invisible processes occurring around us, as a means of giving us more agency in a future world of ubiquitous computing.

For example, we understand the amount of matter a box contains by its weight. Thus, using weight to describe the amount of data contained in a memory drive may also be effective.

Augmented reality is one of the tools which has the potential to create effective experiential augmentations, however the way it is currently used / imagined relies heavily on iconic and symbolic conventions. The next section will examine the pitfalls of this type of augmented reality.

POPULAR VISIONS OF AUGMENTED REALITY

This section examines how augmented reality interfaces of the future are currently imagined, and what might be wrong with this approach and way of thinking.

How is augmented reality defined in this thesis

In this thesis, augmented reality is defined as a form of ubiquitous computing. As augmented reality uses reality as a base, it is a method of creating closer integration between computing and the context of our everyday lives. Additionally, while many examples cited in this thesis relate to visual augmented reality, this thesis does not define AR as exclusively visual. Augmented Reality in this study is defined as a general overarching term for technology that is able to augment our experience of reality, whether that be visual, aural, kinesthetic, olfactory, or gustatory.

Finally, this thesis takes the stance that since augmented reality is a form of ubiquitous computing, it should adhere to the calm experiential language of indexical visualization.

The way augmented reality is currently imagined

Many popular and commercial visions of AR conceive it as a way to project traditional computer screen interfaces onto reality. Using the same vocabulary to communicate in a physical world as traditional computing, floating screens do not meet the criteria of calmness, nor do they augment our understanding and relationship with our context. They are actually windows into a virtual reality, distracting us from the real one.

Criticisms of such future visions can be seen in works such as Hyper-Reality by designer Keiichi Matsuda. In Matsuda's video, we can see the world of overlaid screens taken to an extreme. He creates a suffocating world where augmented reality overlays dominate the main character's visual and audio field, obscuring the reality they are meant to augment.

Floating Screens: The screenshot below is from Hyper-Reality Keiichi Matsuda's vision of a future overlaid with AR interfaces (Matsuda, "Hyper-Reality").

Matsuda's "Hyper-Reality", and similar commercial visions of AR, are the opposite of both Weiser's and Offenhuber's description of calm. These visions use symbolic or iconic overlays that require heavy interpretation, and there is no way to understand the overlaid information without momentarily taking oneself out of the real world context. They cannot be interpreted, in Offenhuber's words, "without too much effort or with the background of attention" (293). This thesis investigates a more experiential direction of augmented reality— one that meets the challenge of invisibility, while also addressing the challenge of calmness.

Building blocks of an experiential augmented reality

In the book "Make it So", Nathan Shedroff and Christopher Nossel analyse the usability of interfaces from science fiction movies. One of the design lessons they learned was that "...designers should be careful not to simply transfer metaphors from early GUI days, but to question them fundamentally and redesign where warranted" (57). With the goal of leaving behind traditional GUI norms and building a language for calm, experiential augmentations in AR, work for this thesis turned to surveying possible building blocks from which augmentations could be created. These building blocks are examined in the next section.

DRAWING FROM FAMILIARITY

Familiarity, schema, metaphors.

Schemas and familiarity

In the book "Social Cognition: An Integrated Approach", Martha Augoustinos and Iain Walker outline the concept of schemas, "...a mental structure which contains general expectations and knowledge of the world" (33). By categorizing information, schemas allow us to have "...some sense of prediction and control of the social world" (33). Augoustinos and Walker's' research, in turn, draws on the experimental work by Eleanor Rosch. Rosch found that we categorize things through comparison with representative or "prototype" subjects. "For example, people judge robins and sparrows to be better examples of the category 'bird' than emus and penguins". (Augoustinos 34). Therefore, one way for augmented reality to enhance the understanding of novel computing embedded objects, is to draw similarities to schemas and prototypes of objects to which we are already familiar.

What schemas mean for this thesis

In "Where The Action Is", Paul Dourish describes the advantages of drawing from our familiarity with the world in the design of technology. Tangible computing for example "...attempts to capitalize on our physical skills and our familiarity with real world objects. It also tries to make computation manifest to us in the world in the same way as we encounter other phenomena, both as a way of making computation fit more naturally with the everyday world and as a way of enriching our experiences with the physical" (Dourish 102). Our familiarity of the world includes schemas of phenomena, and just like in tangible computing, these schemas can be used in experiential augmentations in AR. This thesis sees augmented reality as a tool to manifest the invisible side of objects, by linking the invisible with schema of familiar experiential phenomena.

Metaphors

To be able to use schemas to manifest hidden processes within objects, we have to first understand how we use schema of one subject to inform our understanding of another. One way to uncover our process is through linguistics. The metaphor of a mind as a machine is a usage of the schema we have of machines to better describe the workings of the mind. Moreover, in the book "Metaphors We Live By", Lakoff states that "The most important claim we have made so far is that metaphor is not just a matter of language, that is, of mere words. We shall argue that, on the contrary, human thought processes are largely metaphorical" (Chapter 1). Lakoff's claim is that we do not speak in metaphors to better describe what we think, but that they are a direct reflection of the way we think. We naturally mix and compare schemas when trying to understand things we experience.

Since metaphor is able to create a comparison between schema, and the comparison of schema can be used to manifest invisible processes in objects, we now need to determine how the metaphor can be delivered. For the technique of delivery, this thesis references conventions in tangible and 2d data visualization.

Lakoff's metaphor types:

Orientational: A metaphor involving spatial relationships, that "organizes a whole system of concepts with respect to one another" (Lakoff Chapter 4). Examples would be "healthy is up: rising from the dead" versus "sick is down: He fell ill".

Structural: "Where one concept is metaphorically structured in terms of another" (Lakoff Chapter 4). An example would be "argument is war", where a source "war" provides frameworks to understand the target "argument".

Ontological: "Ways of viewing events, activities, emotions, ideas, etc., As entities and substances" (Lakoff Chapter 4). An example would be the personification of life in, "life has cheated on me".

DRAWING FROM DESIGN FOR TANGIBLES

A study of strategies used in the design of tangible interfaces.

Using physical metaphors to represent digital processes

The design of tangible interfaces can be thought of as a push to use physical metaphors to make digital interactions more concrete. In his thesis, Matthew Gorbett explains that "...using physical affordances and physical interaction metaphors to suggest appropriate ways to use the object's digital capabilities. The need for conscious interpretation of arbitrary lexical commands or symbols is reduced through a design language which appeals to a user's past experiences with physical. This also allows the digital properties of the object to be used in new and creative ways" (29). According to Gorbett, physical metaphors are a way to tap into a person's experience with the physical world, and map this knowledge onto digital interactions.

The success of such metaphors, according to Gorbett, depends on three design principles.

1. Coupling: A measure of how closely an interaction's cause and effect are related.

2. Transparency: The degree to which the interaction occurs without need of conscious interpretation.

3. Mapping: Governs the scale at which physical interactions can manipulate the digital. For example whether a physical object maps to a file in the digital world, or an entire folder of files.

Following are ways Gorbett's principles are applied in experiential augmentation.

1. Coupling: Experiential augmentation deals with indexical visualization, a type of visualization that links cause and effect. The principle of coupling provides a way to describe how closely and intuitively cause and effect are linked.

2. Transparency: This thesis presents experiments which link schema of familiar and unfamiliar objects/phenomena. In experiential augmentation, transparency describes the how well the schema fit together.

3. Mapping: The principle of mapping is the same in tangible computing as in augmented reality, it provides a way to describe how well a representation targets an underlying process.

DRAWING FROM 2D VISUALIZATION

A study of strategies used in the design of data visualisations.

Lessons from data visualization

Design for 2d visualization has a large set of theory for representing abstract information in understandable ways. In "Data Points", Nathan Yau explains "When you visualize data, you represent it with a combination of visual cues that are scaled, colored, and positioned according to values. Dark-colored shapes mean something different from light-colored shapes, or dots in the top right of a two-dimensional space mean something different than dots in the bottom left" (Chapter 3). Furthermore, the ability for a viewer to interpret a visualization depends on the skill of the designer in combining data sets to the "ingredients" of visual cues, coordinate system, scale, and context.

Of these categories, visual cues and context were the most useful for the thesis. Visual cues break down the different building blocks that can be used to create a visualization: color, shape, line direction. These cues are referenced in this thesis when building visualizations in the real world. Context describes how the medium on which visualizations are drawn can give information on the visualization itself. When using AR to augment objects in the environment, the objects become the context, and interpretation of a visualization is affected by the identity of the object.

Lessons from comics

In “Understanding Comics”, Scott McCloud explains the meaning of “icon” in the world of comics. They are an “image used to represent a person, place, thing or idea (27). Icons, McCloud explains, can appear in varying degrees of abstraction, and more abstract images can actually have clearer meaning. “When we abstract an image through cartooning, we’re not so much eliminating details as we are focusing on specific details. By stripping down an image to its essential “meaning” an artist can amplify that meaning in a way that realistic art can’t” (30). Abstraction can not only focus the viewer into specific types of meaning, but also has more universality in its application. A line drawing of a face for example is able to represent more people than a photograph.

When interacting with objects, we see those objects at varying degrees of abstraction. When a book is on the ground, it is just a general object that needs to be returned to its rightful place. When we are reading a book however, it becomes a specific world in which we can be immersed. The book cluttering the floor and the immersive story book are the same object, but have different schemas. In experiential augmentation, it is important to understand the degree of abstraction with which we are viewing an object, in order to target the correct schema.

FIT

Overall concerns when bringing together the building blocks of familiarity and visualization.

In “Things that make us smart”, Don Norman introduces the concept of fit. There is a fit between the person and artifact, that creates a system that is smarter than either alone. There is also a fit between representations to task, where the way something is visualized creates a better understanding of the objects, and the task at hand. The job of the interface designer is to find a surface representation which fits a computational objects’ internal processes.

In the previous sections we have established that the invisible side of objects can be manifested by linking them to familiar phenomena and that this linkage can be delivered through indexical visualization. Through the application of Norman’s concept of fit, a successful experiential augmentation is illustrated as an intuitive three-way fit between a person’s schema of the object, schema of the phenomena, and interpretation of the visualization. This thesis will provide a model to categorize experiential augmentations based on this three way fit.

SUMMARY OF FRAMING

The framing of experiential augmentation began with the review of two design challenges we face as we move into the world of ubiquitous computing. The first is the need for our devices to communicate invisible processes, such that we do not lose agency over the world in which we live. Augmented reality has the potential to be a tool to communicate the invisible processes of objects. However, current visions of augmented reality fail at the second challenge of ubiquitous computing, which indicates the need for communication to be conveyed in a calm manner. One method of calm communication is to mimic the qualitative and experiential language of the world. This language has the potential to drive the design of augmented reality to be more situated within the physical world, rather than overpowering it.

The following sections will describe experimental work aimed at manifesting the invisible actions and characteristics of objects by giving them simulated physical properties through a process this thesis calls "Experiential Augmentation".

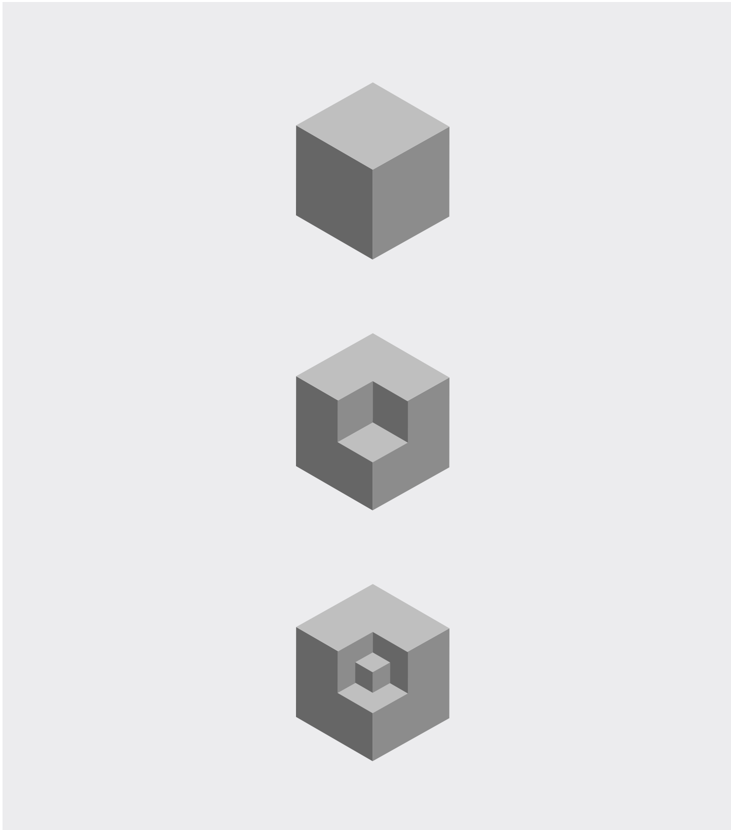
Chapter 2

EXPERIENTIAL AUGMENTATION: FIRST ITERATION

FIRST ITERATION: INTRODUCTION

The first set of experiments created for this thesis focused specifically on the physical qualities of shading and shadow and the question of whether manipulating these attributes can help communicate invisible processes within objects. Since shading and shadow delineate the form of an object, their manipulation in augmented reality has the potential to create dynamic affordances. The ability for objects to alter their own physical affordances will give them a larger vocabulary with which to describe similarly dynamic inner processes.

Altering Shading: Manipulating the way an object is shaded will manipulate the form of the object, allowing for dynamic affordances.



As the projection of shading and shadow through AR is still a subject under research, the use of altered images and videos were chosen over a working AR prototype to focus on the meaning respondents are able to glean from this type of visualization, rather than solving the problem of technical execution.

Publication

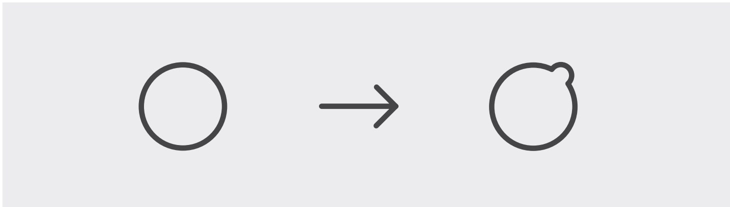
This set of projects was published as a work in progress paper titled "ShapeShift: Mediating User Interaction Through Augmented Shading and Shadow" at the 2017 Tangible, Embedded and Embodied Interactions conference. Following is a redacted description of the ShapeShift set of experiments, the full paper text can be found at: http://dl.acm.org/citation.cfm?doid=3024969.3025088

Exploring shading / shadow

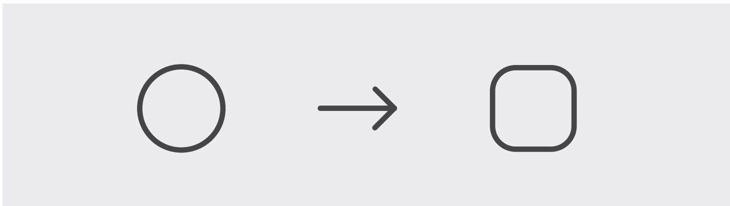
Shading and shadow are form-giving qualities of an object. These attributes play two main roles in perceiving the object: (1) they delineate physical properties of the object (form and texture) and (2) they contextualize the object's relation to its environment. The aim of this work is to extend the ability of the two form giving qualities to cause changes in the perception of an object, allowing for new affordances and interactions to emerge. By doing so, we can enable hardware interfaces to be perceived as malleable as software interfaces.

This set of experiments introduces four examples of shadow and shading manipulation to illustrate its potential for shaping interaction and understanding:

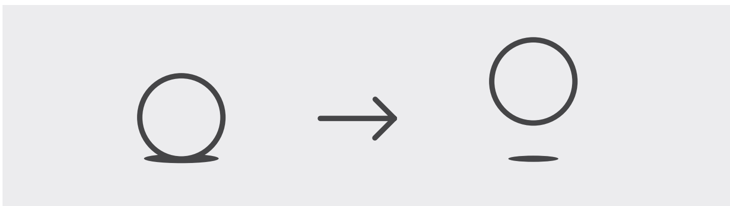
1. Local shading manipulation to change an object's local form



2. Full object shading manipulation to change overall form



3. Shadow manipulation to decrease an object's weight



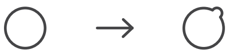
4. Environmental shading manipulation to increase an object's weight

EXPERIMENTS: VIDEO

Video

A video titled “ShapeShift” introducing all experiments can be found at: http://www.dixonlo.com/work/experiential.html

EXPERIMENT 1: LOCALIZED SHADING CHANGE



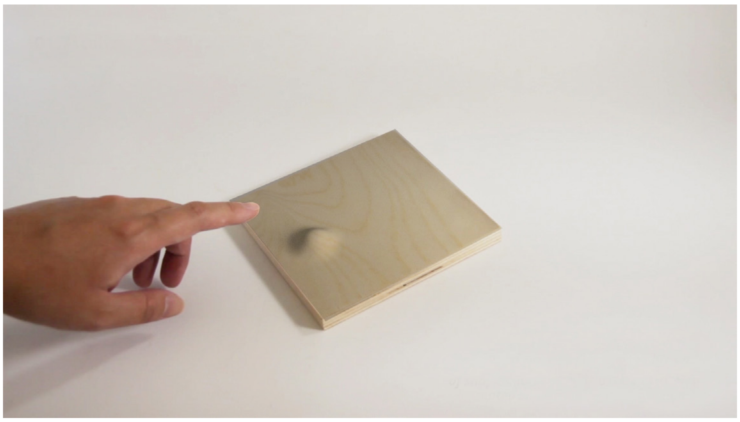
Localized shading manipulation gives the illusion of shape change to targeted areas of an object.

Applications in current devices

In traditional digital interfaces, designers are able to highlight or de-emphasize on screen controls through manipulation of digital properties such as color and opacity. This creates a clear hierarchy guiding users to the correct interactions. By creating the illusion of elevation change through manipulation of shading in AR, we can create hierarchy in hardware interfaces in areas where they were previously nonexistent . This is especially useful for devices void of a screen-based interface.

Local shading change

Press here: Localized shading changes are able to create affordances that explain how an object should be used. In the image on the right, the object is asking to be pressed in a specific location.



Switches: The set of switches on the left are not altered. On the right set, localized shading manipulations increase elevation to emphasize the top button.

EXPERIMENT 2: FULL OBJECT SHADING CHANGE

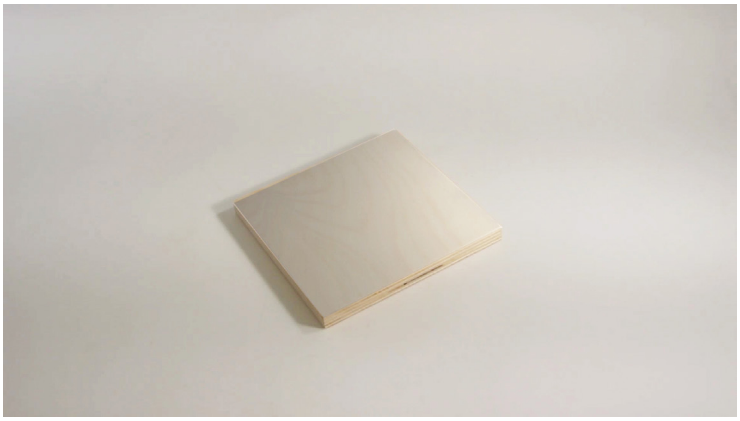
Full object shading manipulation gives the illusion of overall form changes in the object.

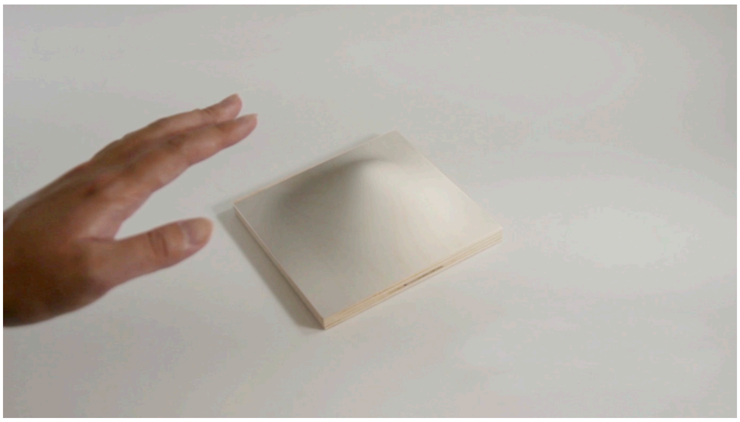
Applications in current devices

In traditional interfaces, the hover or mouse over button state brings attention to an interactable control. Full object shading manipulations allow physical objects to do the same, calling attention to a single object over others nearby.

Traditional interfaces also use form change to signal that a button is active, or has been pressed. Form change in physical objects can likewise signal an active state.

Full object shading change





Pick me up: The object reshades itself to give the illusion of bending toward the user. This gives the user a signal to pick up or otherwise interact with the object.

EXPERIMENT 3: SHADOW CHANGE

Manipulation of the shadow casted by objects can give them a feeling of weightlessness.

Applications in current devices

The illusion of variable weight can be used for a variety of purposes. It can be used to visualize state changes within the object. For example, when files are deleted from an external hard disk, the disk can begin to float to indicate that it is unburdened. This illusion can also be used to signal priority; a higher priority document can float higher on a desk for example. Variable weight can also be used to imbue objects with animalistic qualities or emotion; a floating object can be seen as happier, or less formal.

Shadow change

Floating things: Casted shadows show an object's relationship to surfaces. By manipulating the location of an object's shadow, the object can be given the illusion of weightlessness.

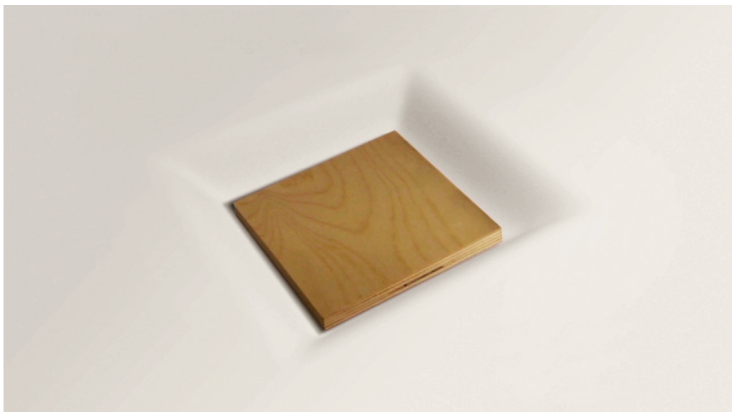
EXPERIMENT 4: ENVIRONMENTAL SHADING CHANGE

Manipulation of shading of an object's immediate surrounding can give the object an illusion of weight.

Applications in current devices

A sinking object gives a sense of burden. For example, a smartphone can gradually sink into the table surface under the weight of accumulating unchecked notifications. A USB memory drive can sink into the table under the burden of the data it contains.

Environmental shading change



Sinking things: Reshading the immediate area around an object can give the illusion that the object is heavy and sinking into a surface. Even a hard surface can be made to look like it is soft and malleable.

REFLECTION

Changes in shading are able to create an illusion of shape change within a physical form for holistic object augmentation. Shadow manipulation and local area shading manipulation were both successful in creating the illusion of an object with variable weight. However, the extent of the illusion is contingent on the shape of the object; for example, it is easier to create the illusion of shape change on flat, non-textured surfaces. Additionally, on see-through augmented reality platforms, there is a challenge of displaying shadows when rendered pixels blend additively with the background.

This early set of experiments received a range of feedback. With current day objects in mind, respondents thought that the concept of ShapeShift may be useful in medical training. Objects on a surgeon's tray are laid out in specific arrangements, and it is important that there is nothing blocking their view of instruments and their patient. Assuming a world of pervasive AR, using shadow for full body form change and weight change to indicate the correct instrument to use could be less intrusive than a disconnected textual overlay. This feedback was encouraging as a lower level of intrusiveness is the goal of creating a calm version of AR.

Chapter 3

EXPERIENTIAL AUGMENTATION: SECOND ITERATION

SETTING UP THE EXPERIMENTS

The first iteration set served as proof of concept that manipulating the weight and form of objects could be used to explain hidden or abstract information in objects. Having gained experience changing the physical attributes of objects, the next step of the thesis tested a wider set of experiments in a more systematic fashion to understand and categorize the types of meaning respondents gleaned from experiential augmentation. The set of experiments was expanded to seven groups of three, totalling twenty one. Each group of three experiments represented the alteration of a type of physical phenomena, for example the transparency of the objects, or the color of the object. Each group of three consisted of a control object that was thought to have no underlying process to visualize, a complex object for which visualization of the underlying may be difficult, and a simple object for which visualization would be easier. In the introduction, Donald Norman's concept of fit was cited as the governing factor of a successful experiential augmentation. This experiment design allows the comparison of different levels of fit for each type of augmentation.

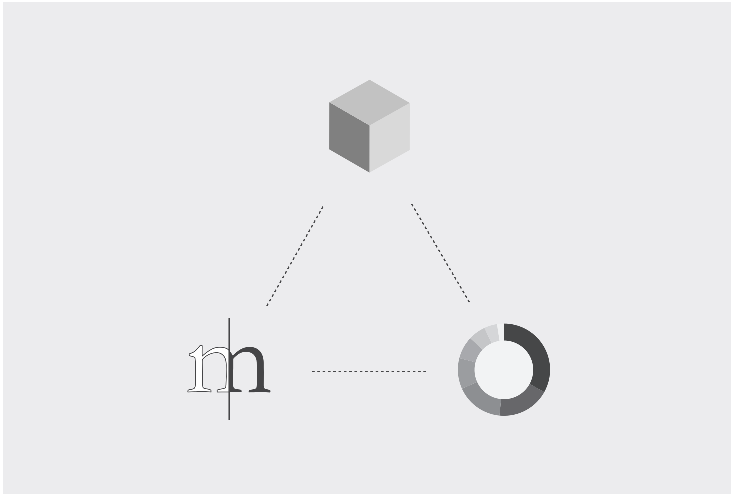
Just as in the first iteration, the focus of this study was to gather a large body of interpretations of meaning as a guide for communication designers working in the augmented reality space. For this study, the use of altered images and videos were chosen over working AR prototypes, as the technical problems of executing these augmentations are still under research.

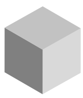
The experiments were tested through eight in-person interviews and an anonymous survey with a total of thirty five participants. Each participant was presented with images of everyday objects that included altered physical attributes. Participants were then asked to interpret the meaning of the alteration, and elaborate on the reasons for their interpretations.

The next section introduces a model used to categorize and understand the experimental results.

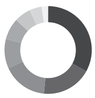
EXPERIENTIAL AUGMENTATION MODEL

The second iteration results were collected as long form written responses. These responses were analyzed to understand the components of a participant’s understanding of augmentations. The analysis revealed that participant responses varied with their understanding of the object being augmented, understanding of the representation, and the type of meaning they interpreted. These three categories form the basis of the experiential augmentation model.

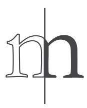




The first corner of the model represents the viewer’s understanding of an object. For example, one experiment featured varying results depending on whether the participant identified the object as a debit or credit card.



The second corner of the model represents the viewer’s understanding of the augmentation. This seemed largely dependent on the clarity of execution of the augmentation.



The final corner of the model represents the type of meaning being interpreted by the participant. Categorizations for meaning were adapted from metaphor classifications presented in the book “Metaphors We Live By”. They consist of:

1. Metaphor - where one object is compared to another

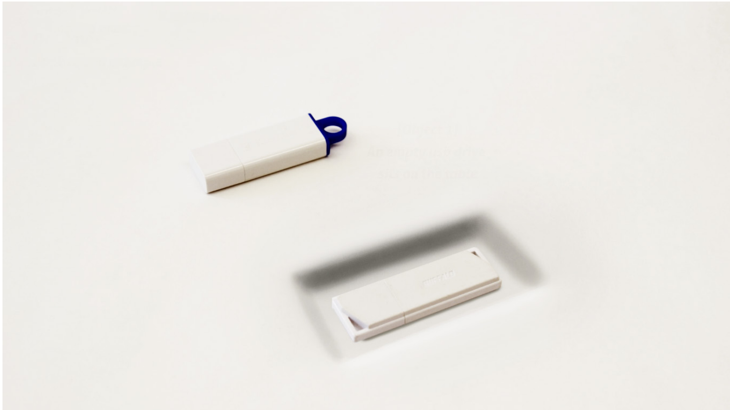
2. Personification - where an object is compared to a living thing

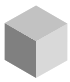
3. Affordance - where the viewer is understanding the augmentations as if they were not augmented reality and actually existed in reality.

4. Notification - where the viewer understands the representation as a call for attention, but without specific instructions.

MODEL APPLICATION: SUCCESS EXAMPLE

In one of the experiments, the area around a USB drive was re-shaded to created the illusion of the drive sinking into the table.





For this example, people either interpreted the drive as a general electronic device, or a more specific container of data.

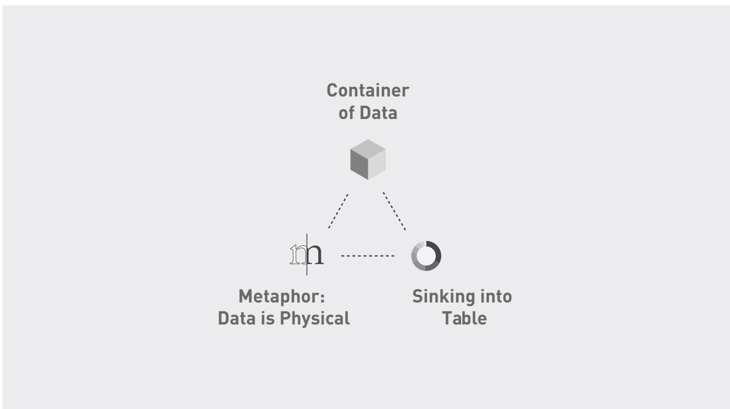
As for the representation, it was interpreted as either the USB drive sinking into the table from its own weight, or that there was a hole in the table, which the drive happened to be sitting in.

Finally, for the type of meaning, observers had a range of interpretations, from drawing a Metaphor from data to physical things, to “Personification” to “Notification”.

Each combination of object, representation and meaning result in different interpretations of the augmentation. Below is a diagram illustrating understanding the drive as a **container of data**, the representation as **sinking into the table**, and the **metaphor of data as a physical thing**. The resulting overall interpretation of this combination is that the drive is sinking into the table because it is heavy with data.

Participant interpretation:

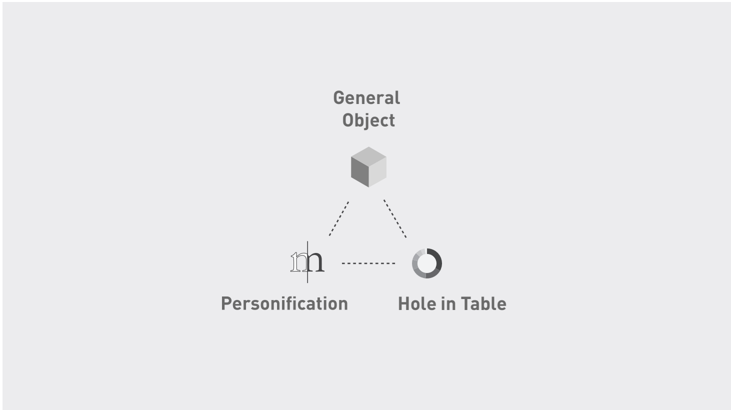
“This drive is sinking into the table because it is heavy with data.”



Alternatively, one respondent saw the drive as a **general device**, the representation as a **hole in the table** that the drive happened to be sitting in, and interpreted meaning using the category of **personification**. This respondent thought the drive looking cozy in its hole, and in its rightful place.

Participant interpretation:

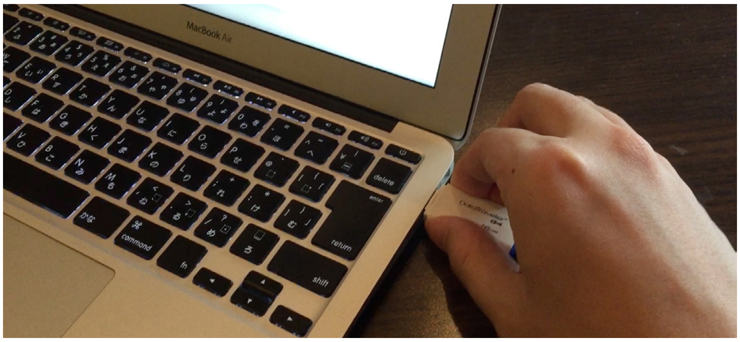
“The drive looks cozy in its hole, it’s in its rightful place.”



MODEL APPLICATION: DISCONNECT EXAMPLE

Data flow: The experiment video titled “USB Plug” can be found at: http://www.dixonlo.com/work/experiential.html

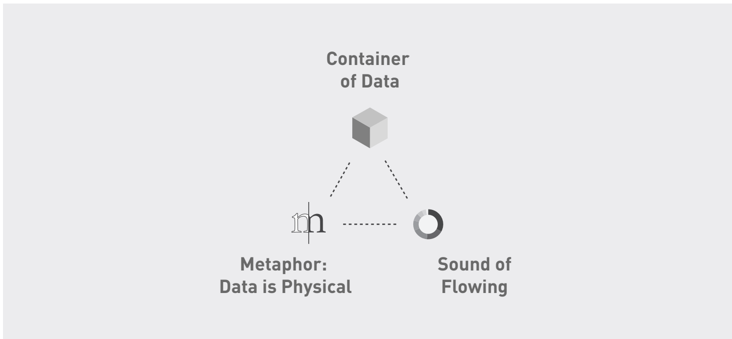
The model is also able to categorize disconnects in interpretation. In one experiment, the sound of flowing water was played over the action of connecting a USB drive.



The most common interpretation was the following:

Participant interpretation:

“Data is being transferred from USB drive to computer.”

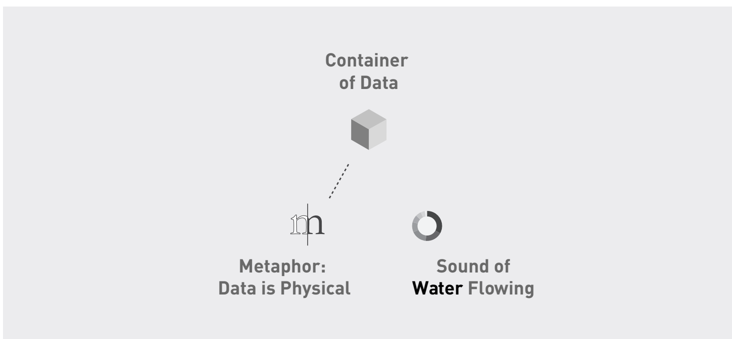


Respondents read the USB drive as a container of data and heard the sound of flowing, which lead them to perceive the metaphor, which links data to a physical thing. The result was the interpretation that data was flowing.

However, within this group, a small contingent felt a disconnect in the sound. They asked why the sound of water flowing was used specifically as they did not like the idea of water near electronic devices, and did not identify the sound of data as being water-like. The specificity of the sound being water flowing, was causing a disconnect with the rest of the object.

Participant response:

“Why aren’t you using a sound that is more like Data?”



DISCONNECT TYPES

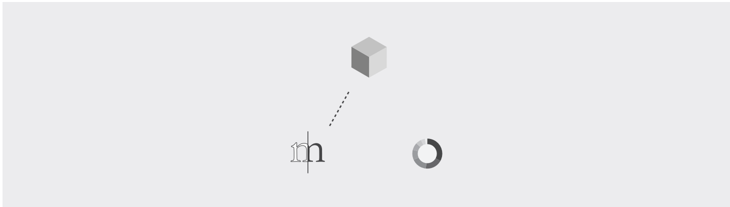
Most disconnects found in this thesis conform to the three following categories.

Representation disconnect

Representation disconnect example responses:

“I don’t see anything happening.”

“I see something happening, but I don’t know why.“

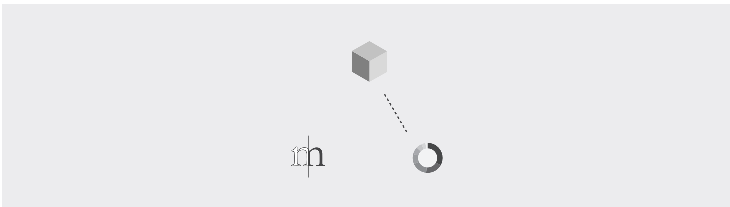


There were two versions of representation disconnect in the results of this thesis. Sometimes, the representation was too subtle, and respondents could not see it. Other times respondents could see the representation, but it does not match their schema of how the object functions.

Meaning disconnect

Meaning disconnect example response:

“It seems like it is trying to tell me something, but I’m not sure what.”

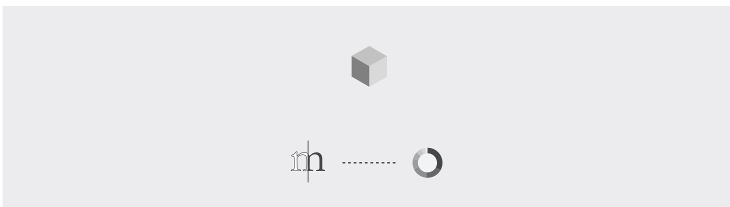


When meaning is disconnected, many respondents default to a general notification interpretation. They understand that the object is behaving out of the ordinary, and that the behavior is a type of communication, but they do not understand what is being communicated.

Object model disconnect

Object model disconnect example response:

“I see something happening, but I don’t understand why this object would behave in this way.”

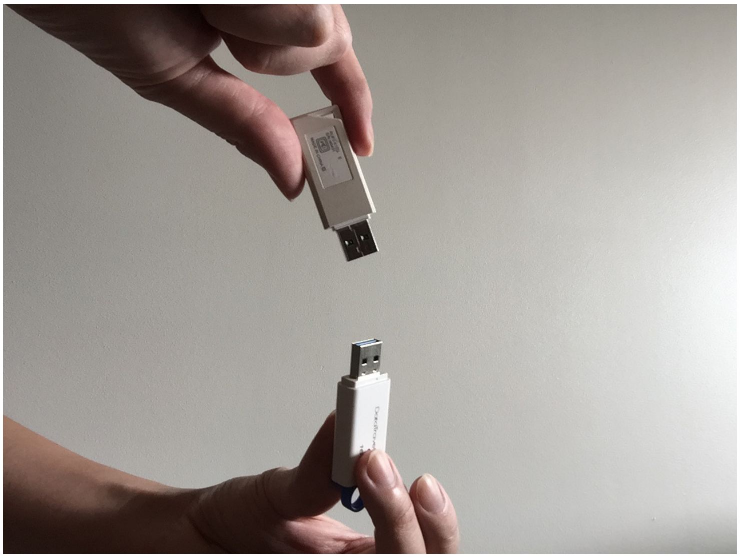


Sometimes the augmentation is rich enough to deliver its own meaning without the aid of an object, however, the meaning conflicts with the viewer’s understanding of the object.

3D MODEL MULTIPLE OBJECTS, REPRESENTATIONS, AND MEANINGS

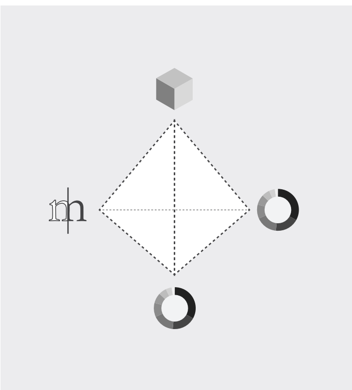
Though the model is able to represent a single object/meaning/representation set, some of the experiments actually featured overlapping representations. In the experiments, overlapping representations usually took the form of an augmentation coupled with a physical interaction language that served to strengthen the representation. An example is an experiment, where the action of pouring from one USB drive to another (physical interaction), is coupled with the sound of water flow (augmentation).

Data pour: The experiment video titled "Data Pour" can be found at: http://www.dixonlo.com/work/experiential.html



Both the action and sound point to the metaphor of data as a physical thing, which can flow, and can create sound. Testing of this project revealed that the combination of action and sound strengthened the metaphor.

This experiment, represented in the model, took the shape of a triangular based pyramid, with two representations, one meaning and one object.



Object: Container of data

Type of meaning: Data is physical

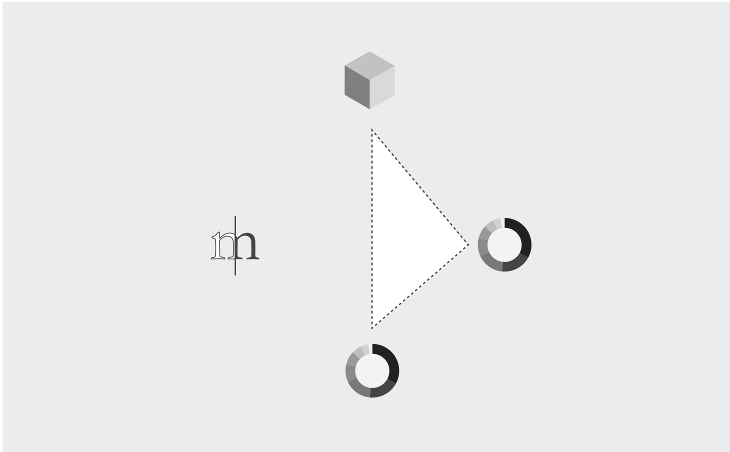
Representation: Sound of flow

Representation: Action of pouring

More complex 3d models can be created when a series of objects, or a series of meanings became part of the system.

3D MODEL DISCONNECT

Though overlapping actions to describe the same metaphor strengthens the metaphor, there is a risk of confusion if the representations do not point to the same meaning. In the model below, two representations don't point to a coherent meaning, causing confusion.



EXPERIMENT OVERVIEW

All experiments related to the use of qualitative and experiential phenomena to explain hidden processes within objects, and they were tested in groups of three. Each set of three pertained to a specific phenomena, such as “fading out” or “losing color”. Each group of three contained a control test, a test with a plausible interpretation, and a test where the meaning of the representation was thought to be difficult to discern.

EXPERIMENT 1: FLOAT

The float series of experiments tests whether respondents are able to link weight changes in objects to invisible processes underlying those objects. Objects used in this experiment were a wood block for control, a debit card and a USB drive. The wood block was assumed to have no underlying process, whereas augmentations to the debit card was intended to be connected to the state of finances, and augmentation to the USB drive was intended to be connected to the data it contains.

Wood block

Floating wood: In the floating wood experiment, respondents were shown an image of a wood block with altered shadows, giving the wood an illusion of weightlessness.

Reflection

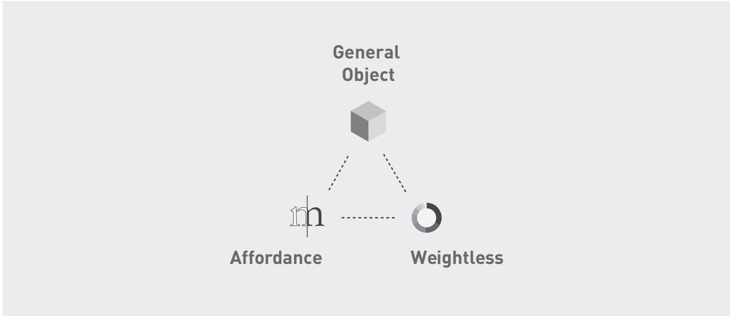
The expectation was that participants would have difficulty interpreting any meaning from augmentations to a wood block, as wood was thought not have an underlying invisible process to be represented. Interestingly, this experiment was the start of a pattern of results where without a coherent connection to meaning or underlying process, respondents would default to understanding certain representations as attention seeking behavior or a notification. In general, floating had a positive and active connotation. Many people responded that the wood block wanted to be picked up, or that it was making itself available to be picked up. Respondents also said however that the reason why it wanted to be picked up was unclear.

Those unable to interpret meaning from the augmentation understandably could not connect floating to any underlying process or property of wood.

Selected interpretations:

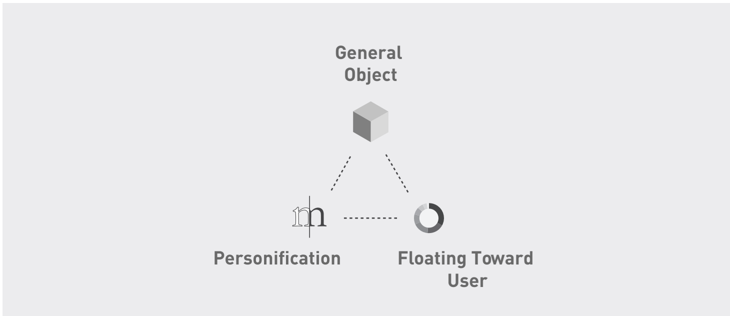
Participant interpretation:

“The wood block is easier to pick up because it is floating, its light.”



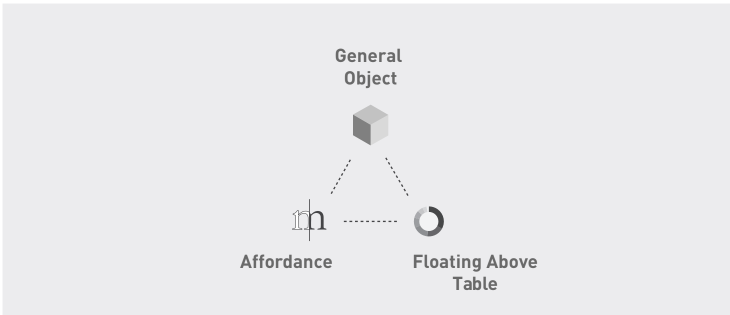
Participant interpretation:

“The wood block is telling me to pick it up.”



Participant interpretation:

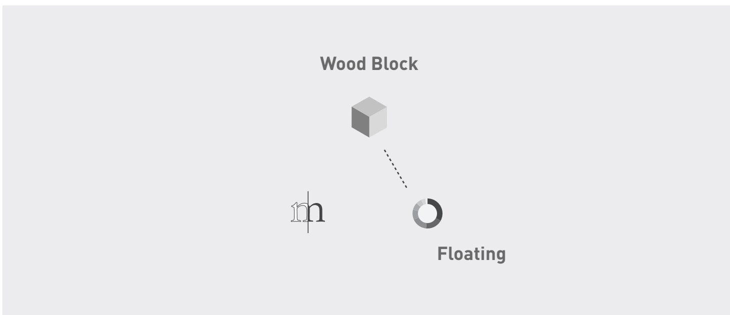
“The wood block is easier to grab because its not longer lying flat on the table.”



Selected disconnect

Participant response:

“I don’t understand why wood would be floating.”



Floating card: In the floating debit card experiment, respondents were shown an image of a debit card with altered shadows, giving the card an illusion of weightlessness.

Debit card

Debit card reflection

Just like in the wood example, floating was interpreted in general as having a positive or active connotation. Interpreted meaning ranged from the card asking to be selected for payment to a reminder that a bill is due. Though the intention was to use the floating as a reflection of the state of the owner's finances, most respondents did not make the connection, choosing to identify the augmentation as a call to action to make a purchase or payment.

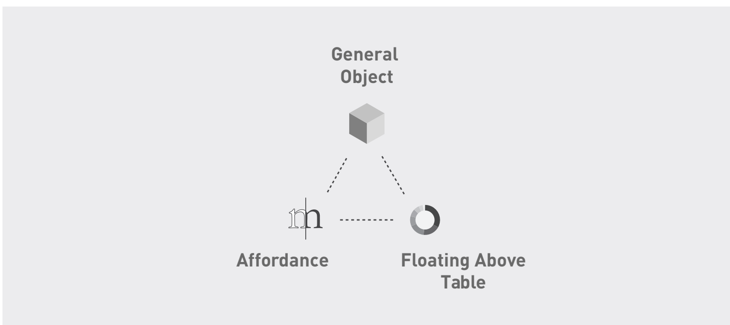
One respondent cited confusion as to whether the card was debit or credit as the cause of confusion in the meaning of the augmentation. Floating, in this case, could mean opposite things, more money, or more debt.

Respondents also noted difficulty in connecting the augmentation to more than a call to use the card itself. Saying that it was hard to imagine the card as containing money or indicating something about finances, because it was too abstract a connection.

Participant interpretation:

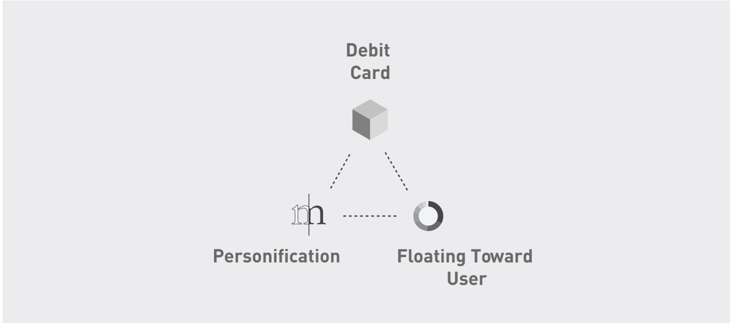
"The floating card is easier to grab than one lying flat on the table."

Selected interpretations



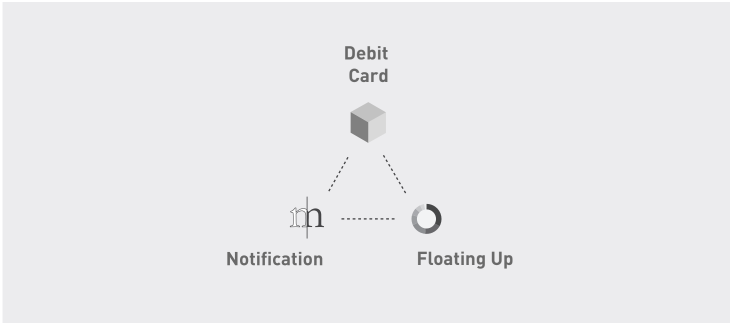
Participant interpretation:

"The floating card is telling me I should use it to pay."



Participant interpretation:

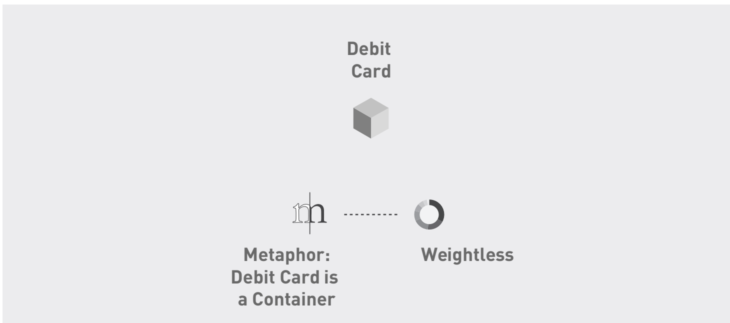
"The floating card is telling me it is usable."



Selected disconnects

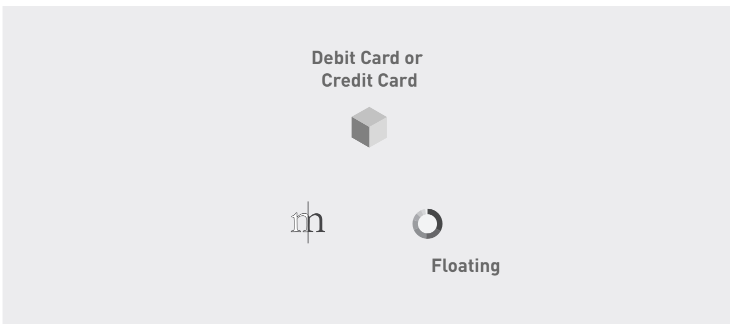
Participant response:

"I understand you are trying to relate weight to the quantity of money contained in the card, but to me, a debit card isn't a container of money."



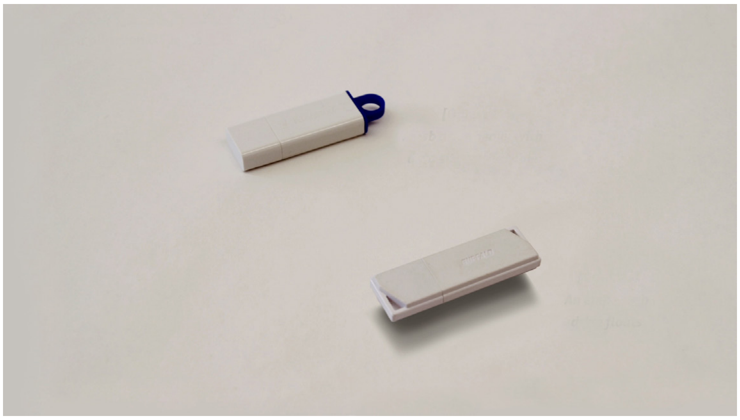
Participant response:

"Is it a debit or a credit card? If it is a debit card, floating may mean that I can spend money, but if it is a credit card, floating may mean I owe money."



USB drive

Floating drive: In the floating USB drive experiment, respondents were shown an image of a USB drive with altered shadows, giving the drive an illusion of weightlessness.



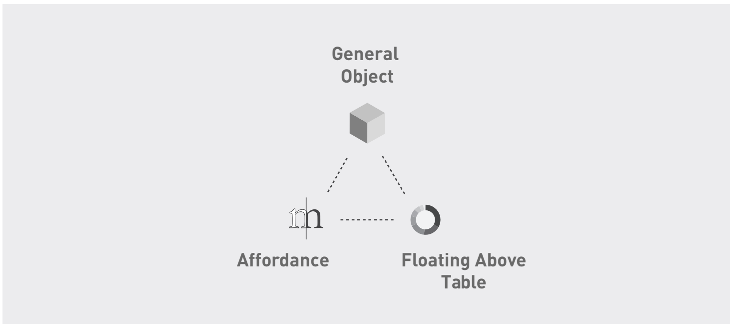
USB drive reflection

Similar to the wood block and debit card, respondents interpreted the USB drive floating as a call to action. The drive was identifying itself as the one that had the important information, or that it was making itself easier for the user to pick up.

Selected interpretations

Participant interpretation:

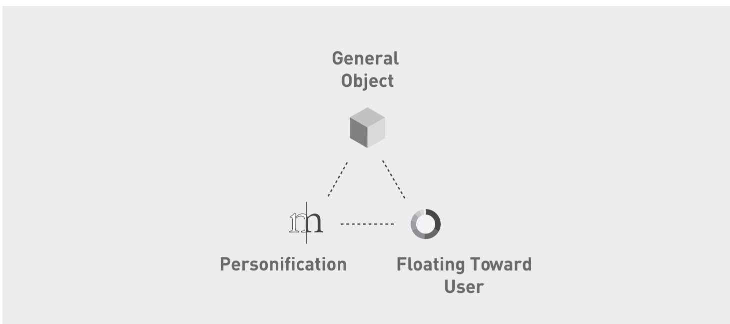
"The drive is easier to grab than one lying flat on the table."



Participant interpretations:

"The floating drive is telling me the information I want is inside it."

"The floating drive is telling me that I should use it."

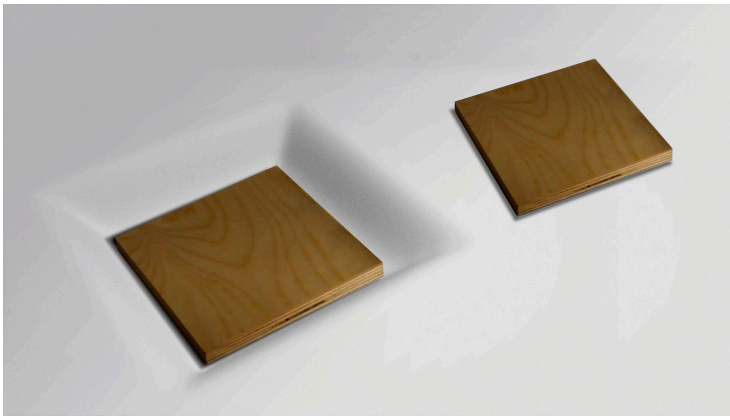


EXPERIMENT 2: SINK

The sink series of experiments tests whether respondents are able to link weight changes in objects to invisible processes underlying those objects. Objects used in this experiment were a wood block for control, a debit card, and a USB drive. The wood block was assumed to have no underlying process, whereas augmentation to the debit card was intended to be connected to the state of finances, and augmentation to the USB drive was intended to be connected to the data it contains.

Wood block

Sinking block: In the sinking wood block experiment, respondents were shown an image of a wood block altered to look like it is sinking into the surface it is sitting on.



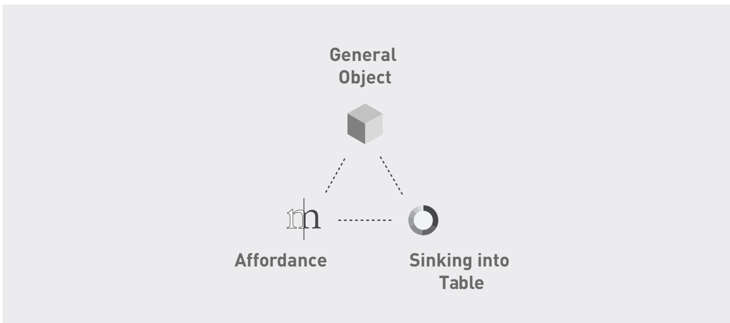
Wood reflection

Most respondents only looked at the augmentation of sinking as a change in the physical quality of the wood, saying that it had become heavier. There was one respondent who mentioned that sinking carried a generally negative connotation, and that something negative seemed to be happening, but they could not elaborate on the specifics of the communication.

Selected interpretation

Participant interpretation:

“The wood is heavy, hard to lift.”



Debit card

Sinking card: In the sinking debit card experiment, respondents were shown an image of a debit card altered to look like it is sinking into the surface it is sitting on.

Debit card reflection

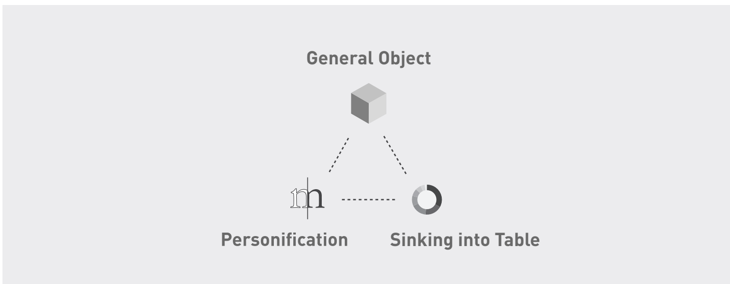
The negative connotation of sinking was more apparent in the debit card experiments. People interpreted it as telling them they are in debt, or that the card should not / cannot be used.

When told that the intention of this example was to connect the debit card augmentation with the money held in the bank account. Respondents mentioned that they did not think of a debit card as a container of money, and therefore it was difficult to connect the weight illusion to the physicality of money.

Selected interpretations

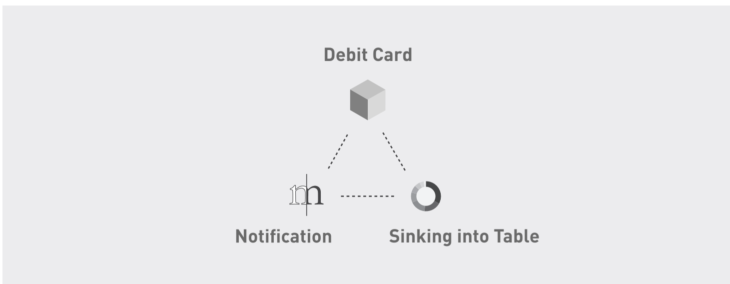
Participant interpretation:

"It's trying to run away from me, the card doesn't want me to use it."



Participant interpretation:

"The card can't be used."



Sinking USB: In the sinking USB drive experiment, respondents were shown an image of a USB drive altered to look like it is sinking into the surface it is sitting on.

USB drive

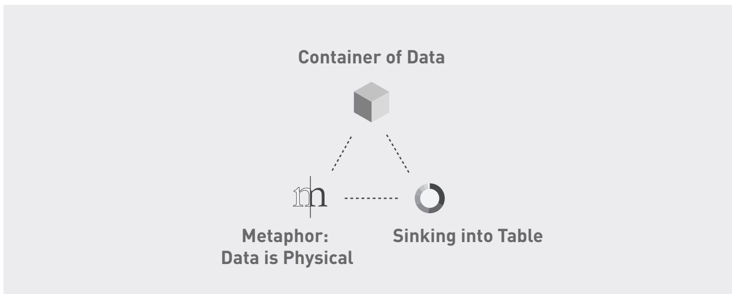
USB drive reflection

Unlike the floating USB drive, respondents were able to connect sinking more easily to the data housed in the drive. Many stated that the drive was full, or that it was heavy with data. Comparing results with the USB floating example, many of the respondents who identified the drive as being heavy with data also interpreted the floating USB drive as calling attention to itself. From their switch it can be inferred that augmentations with negative connotations have less of a chance of being interpreted as a general notification/call to action, and therefore have a higher chance of being connected to a more complicated metaphor, such as data being physical and having weight.

Selected interpretations

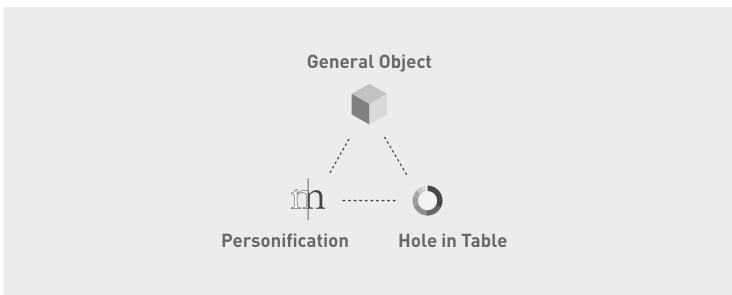
Participant interpretation:

“The drive is sinking because it is heavy with data.”



Participant interpretation:

“I don’t see it as sinking, it looks like there is a hole in the table and the drive is sitting in it. It looks cozy, like that’s where it wants to be.”

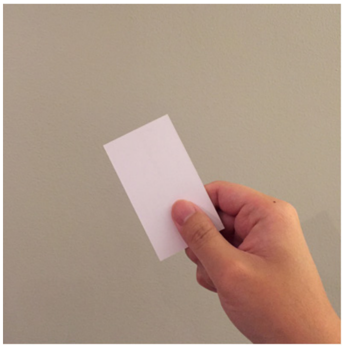


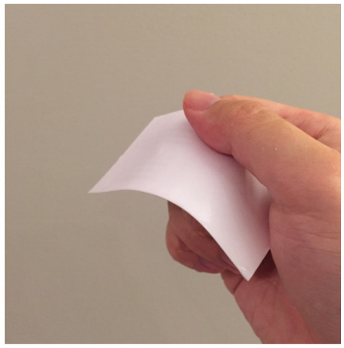
EXPERIMENT 3: RIGIDITY

The rigidity series of experiments tested whether respondents were able to link structural changes in objects to invisible processes underlying those objects. Objects used in this experiment included a blank card, a business card, and a debit card. The blank card was assumed to have no underlying process, whereas augmentation to the business card was intended to illustrate connections to the card owner, and augmentation to the debit was intended to be show connections to the owner's finances.

Blank card

Card: In the card rigidity experiment, respondents were shown an image of a blank card losing rigidity.





Blank card reflection

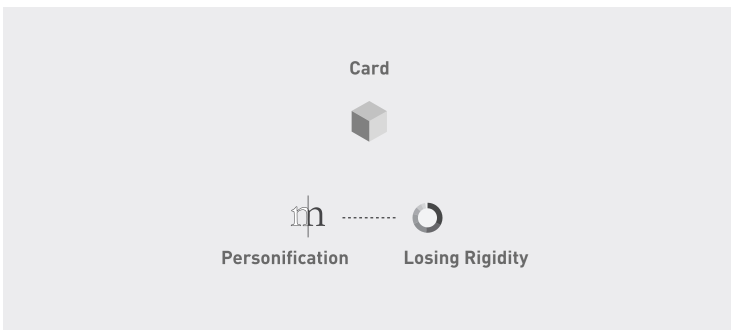
Because the augmentation in this case was an actual physical change in the object, rather than an illusion, many respondents interpreted it as the result of physical action. For example, the paper bent under humidity or heat.

Most respondents, however, could not think of a meaning for the augmentation, saying that they could not understand why a blank card would suddenly lose rigidity. Some mentioned that the card may be trying to stop itself from being used, but could not identify what it meant to use the card. A single respondent who found meaning in the alteration, did so by seeing the card not as a blank control object, but as something to be written on, the resulting interpretation was not to use the card as writing material.

Selected disconnect

Participant response:

"It seems like it's telling me not to use it, but I don't know what "use" means with a blank card."



Business card

Business card: In the business card rigidity experiment, respondents were shown an image of a business card losing rigidity.

Business card reflection

In the business card example, it became clear that losing rigidity had a general negative connotation. Additionally, it was quite easy for respondents to think of the card as a representation of the person from whom the card was received. Those who made the connection to the card giver said that it looked like the person was untrustworthy, or even dead. Those who did not connect the meaning of losing rigidity to the card giver interpreted the card containing invalid or outdated information.

In this example, respondents also commented that this representation may have privacy concerns, as it would be awkward for the card giver to realize they were seen as untrustworthy. This shows the desirability of a representation as a factor in the interpretation of meaning. Given two equally plausible interpretations, respondents may lean toward the one they find more usable or desirable.

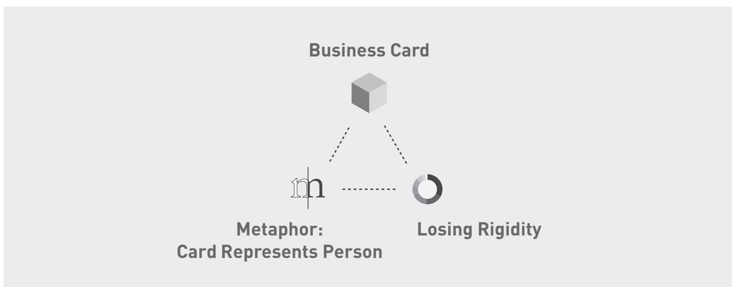
Selected interpretations

Participant interpretation:

"The card's information is no longer valid."

Participant interpretation:

"I feel like I shouldn't trust the person who I received this card from."



Debit card: In the debit card rigidity experiment, respondents were shown an image of a debit card losing rigidity.

Debit card

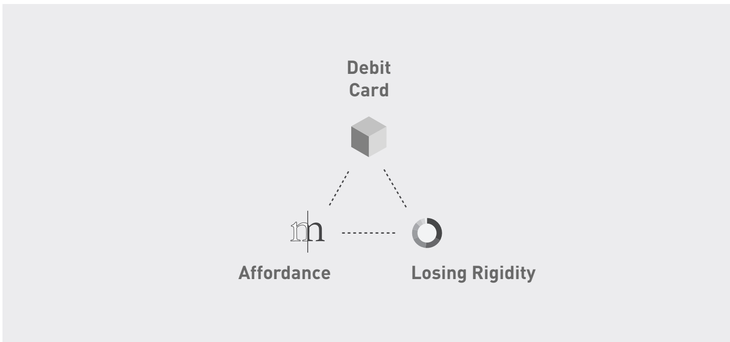
Debit card reflection

In the debit card experiment, respondents' comments focused on the process of using the card, saying that a card with no rigidity would be difficult to swipe, and therefore was indicating a lack of money, expiry, or even that the user may be a victim of fraud.

Selected interpretations

Participant interpretation:

"It doesn't look like I could swipe the card or use it at an ATM machine."

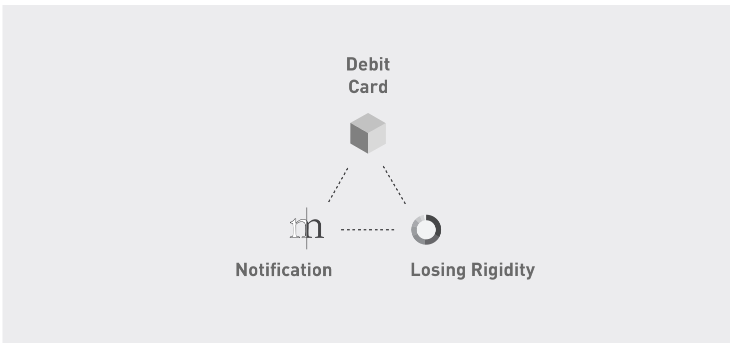


Participant interpretation:

"It is telling me I have no money left."

"The card is losing rigidity to tell me I am a victim of fraud."

"The card has expired."

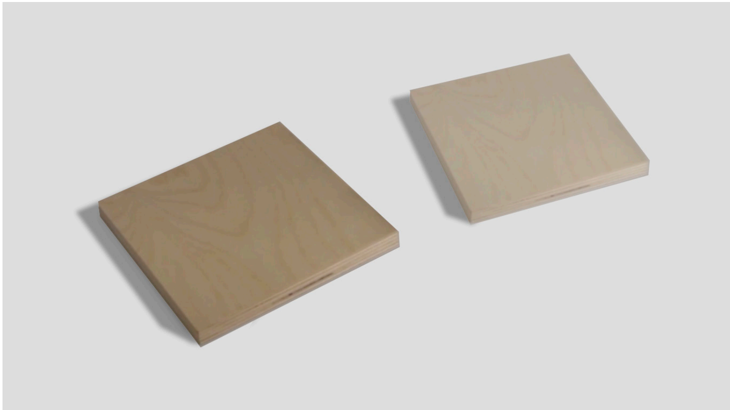


EXPERIMENT 4: FADE

The fade series of experiments tests whether respondents are able to link transparency changes in objects to invisible processes underlying those objects. Objects used in this experiment were a wood block, a debit card, and a smart phone. The wood block was assumed to have no underlying process, whereas augmentation to the debit card was intended to be connected to owner's finances, and augmentation to the smartphone was intended to be connected to battery life.

Wood block

Fading block: In the fading wood block experiment, respondents were shown an image of a wood block becoming transparent.



Wood block reflection

Compared to other control tests, the fading wood experiment resulted in an uncharacteristically low number of "I don't know" responses when asked for interpretation of meaning. This is because respondents identified an underlying process—decay— as being visualized. The faded wood was thought to be rotting, not solid, or of bad quality.

The fade examples also feature a small number of respondents who use pop culture to inform their interpretations. In this example a respondent was reminded of the movie "Back to the Future", where fading out was a sign that someone had traveled into the past and altered the timeline of the object, affecting its existence.

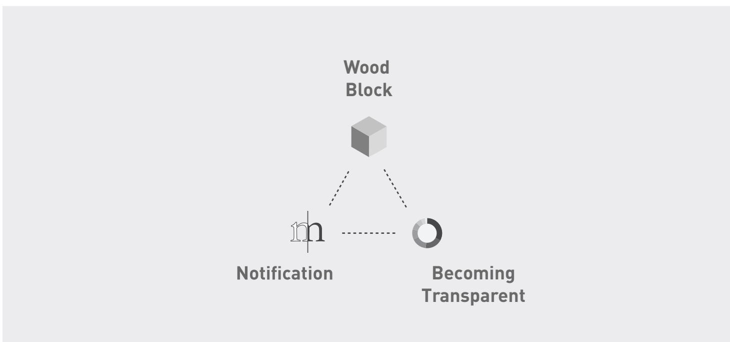
Selected interpretation

Participant interpretation:

"The wood block is weak."

"The wood block is rotting."

"I shouldn't use this block to build things."



Fading debit card: In the fading debit card experiment, respondents were shown an image of a debit card becoming transparent.

Debit card

Debit card reflection

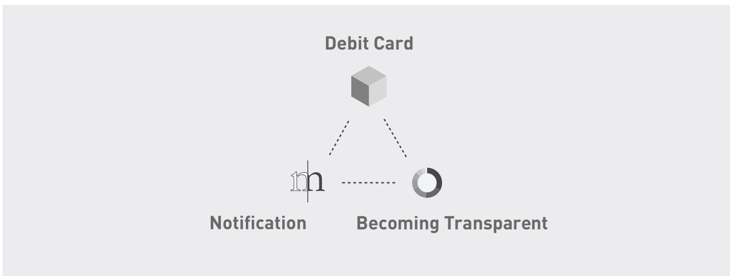
Fading was generally seen as a warning not to use the debit card. This example was most successful out of all the debit card examples in eliciting responses having to do with monetary balance. However, the difficulty of seeing the card as a metaphorical container of money still persisted. One respondent explained that they thought of the card more as an access key to money rather than containing or representing money itself.

Selected interpretations

Participant interpretation:

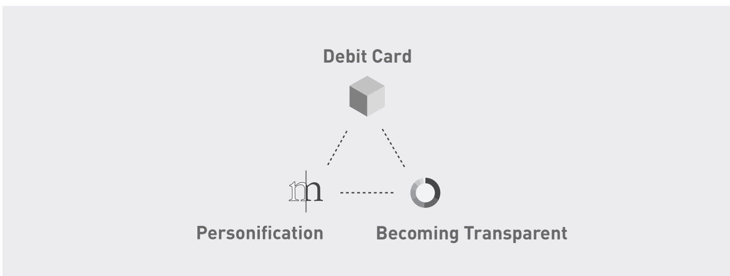
“The card has no money left.”

“The card needs to be replaced.”



Participant interpretation:

“The card looks like its dying, expiry date is near.”



Fading smartphone: In the fading smartphone experiment, respondents were shown an image of a smartphone becoming transparent.

Smartphone

Smartphone reflection

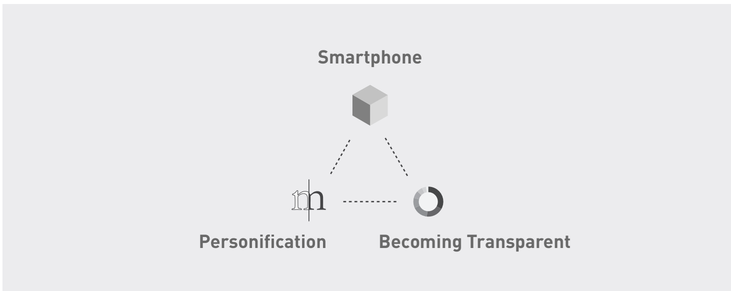
A majority of respondents connected the fading phone with the fading of battery power. Those who did not make this connection thought the phone was in a 'do not disturb' mode, or otherwise disabled, reflecting behaviors exhibited using the customary visual affordances of screen interfaces. Though respondents agreed that the fading represented a loss of battery, they questioned its use in actual products. A smartphone running out of power should ask for attention rather than fade away.

Selected interpretations

Participant interpretation:

"The phone is dying."

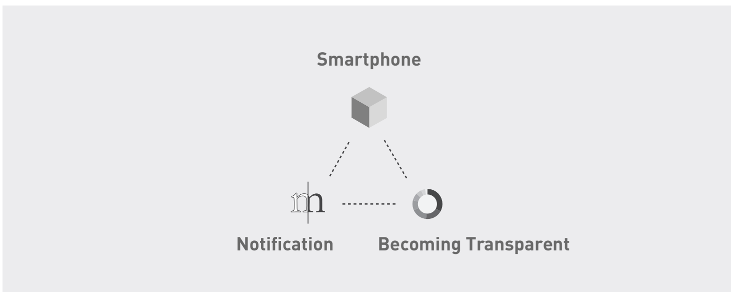
"It's saying I'm losing battery, aaaaah!"



Participant interpretation:

"It's in do not disturb mode."

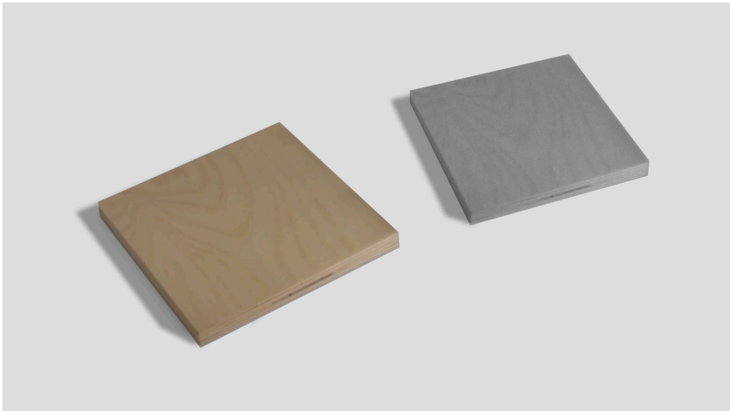
"It's disabled."



EXPERIMENT 5: COLOR LOSS

The color loss series of experiments tested whether respondents were able to link color changes in objects to invisible processes underlying those objects. Objects used in this experiment were a wood block, a discount card, and an apple. The wood block was assumed to have no underlying process, whereas augmentation to the discount card was intended to reflect its validity, and augmentation to the apple was intended to reflect its edibility.

Wood block

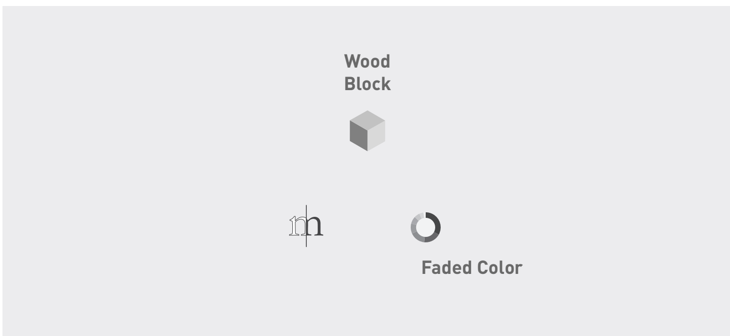


Wood block color loss: In the wood block color loss experiment, respondents were shown an image of a wood block becoming black and white.

Wood block reflection

As the black and white woodblock looked plausible as an actual piece of wood without augmentations, many respondents could not interpret any meaning from the color loss. Those who did notice the color loss found meaning when interpreting the wood block not as control object lacking identity, but as a piece of wood used for sale or construction. Respondents thought the wood looked like it wasn't available for sale, or was weaker than normal and should not be used to build objects.

Selected disconnect



Participant response:

"I don't see anything special happening, it looks like a normal piece of wood."

Discount card color loss: In the discount card loss experiment, respondents were shown an image of a discount card becoming black and white.

Discount card

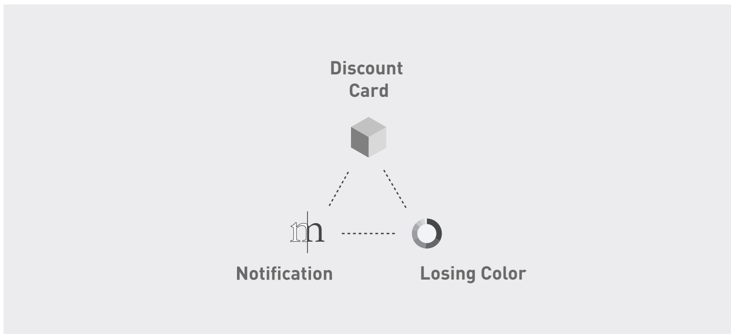
Discount card reflection

The discount card suffered the same problem as the wood block. A black and white discount card did not look out of the ordinary. When respondents were able to compare the augmented colorless card with a normally colored card, they interpreted the card as having become invalid, or reached its use limit. The most interesting response was from one respondent who thought the black and white representation made the card look like a memory, saying perhaps it was an object whose owner had passed away.

Selected interpretations

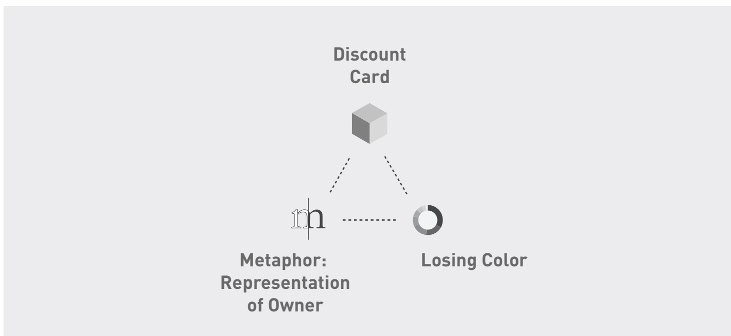
Participant interpretation:

"The card looks like it's no longer valid."



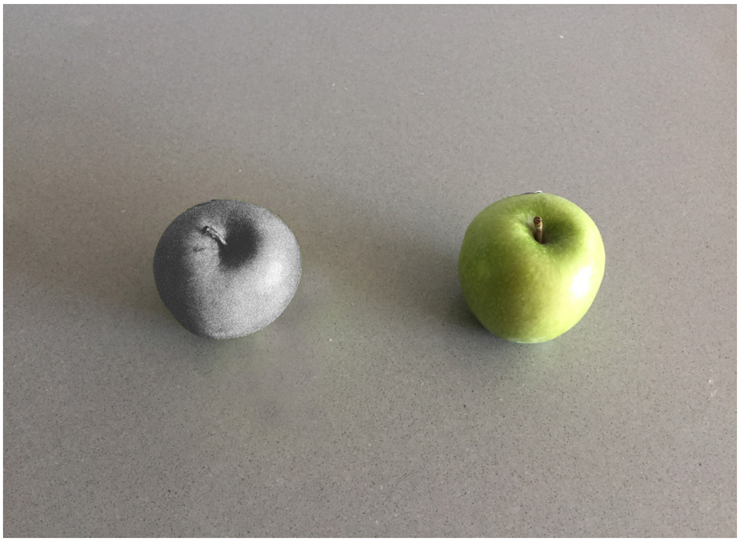
Participant interpretation:

"The card's owner has passed away."



Apple

Apple color loss: In the apple color loss experiment, respondents were shown an image of an apple becoming black and white.



Apple reflection

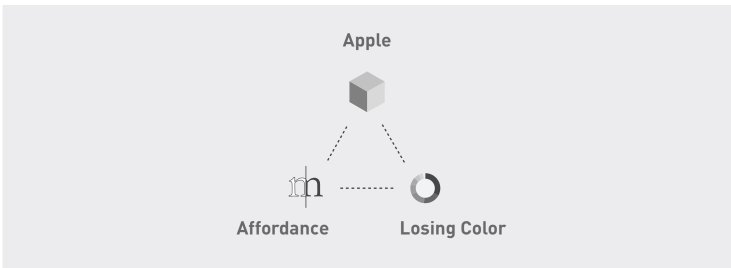
The apple experiment was particularly successful, probably because the apple already uses physical indicators as a sign of expiry. Respondents thought that the loss of color made the apple look "weird" and gave them an uneasy feeling, which would stop them from eating it. They did, however, question why there should be another indicator for such a function when the apple already shows its expiry through color and texture. They mentioned that it may be useful in the avocado, where freshness is more difficult to discern.

Selected interpretations

Participant interpretation:

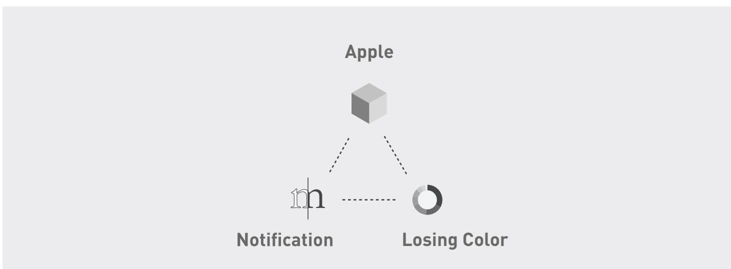
"It looks odd, I wouldn't eat it."

"It makes me feel uneasy."



Participant interpretation:

"This apple is expired."

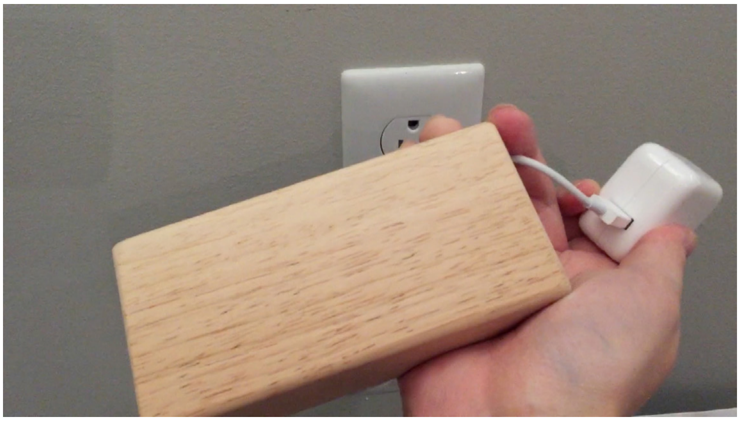


EXPERIMENT 6: FLOW

The flow series of experiments tested whether respondents were able to link the sound of substance flowing to changes in objects and the invisible processes underlying those objects. Objects used in this experiment were a wood block, a smartphone, and a USB drive. The wood block was assumed to have no underlying process, whereas augmentation to the smartphone was intended to reflect power charging, and augmentation to the USB drive was intended to reflect data transfer.

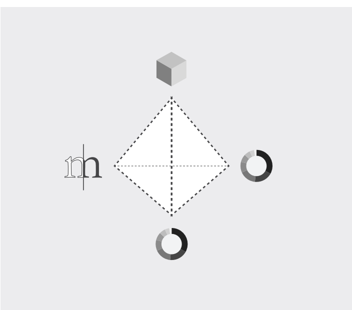
Wood block

Wood block flow: The wood block flow experiment included the action of plugging the wood block into an electrical outlet, coupled with the sound of water flowing. A video of the experiment titled "Wood Plug" can be found at: http://www.dixonlo.com/work/experiential.html



Wood block reflection

The expectation was that the experiment would produce no discernible meaning. In reality, the overlapping representations of plugging in the block and the sound of substance flow altered the respondents' perceptions of the object. Instead of interpreting the object as a normal piece of wood, some wondered whether it was an electronic device made of wood that needed charging. On the other hand, the sound of water gave the impression that something was flowing into the wood. Respondents who viewed the wood as an electronic device interpreted the sound as representing the flow of electricity, keeping both action and representation consistent with their model. Other respondents, however, chose to change their interpretation of the outlet, saying that it was transferring data into the piece of wood, or that it had the ability to fill the wood with actual water.

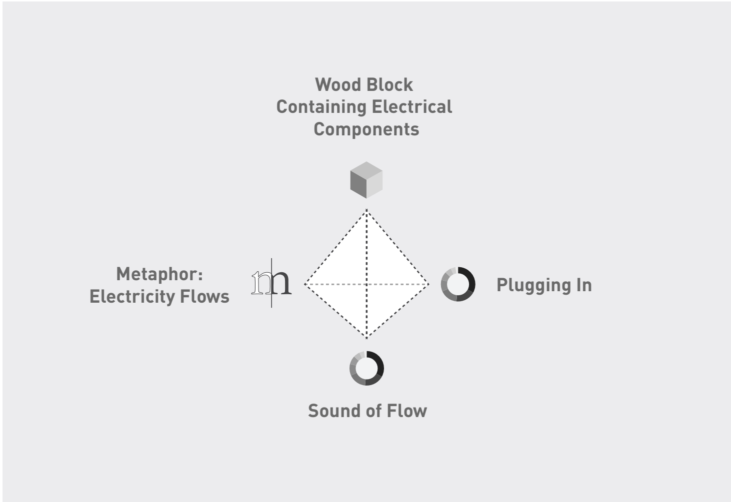


It was impossible to interpret responses using the three-pointed model, as this experiment included one meaning interpretation, two representations, and a system of two objects. This prompted an adaptation of the model to three dimensions.

Selected interpretation

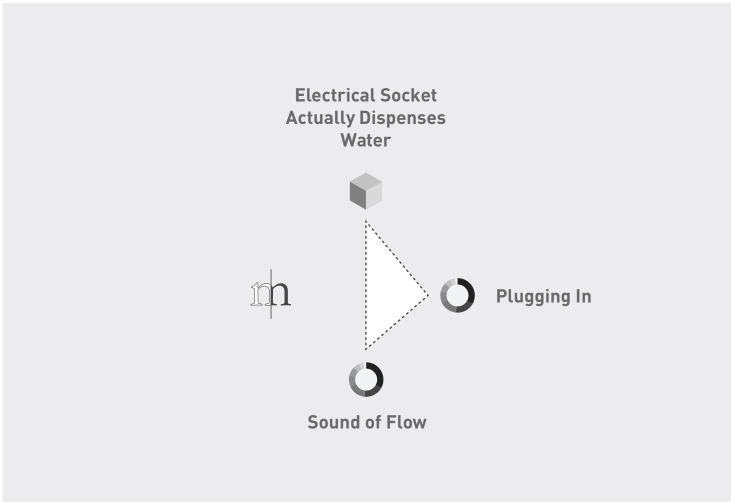
Participant interpretation:

"The wood block is actually an electrical device that needs to be charged."



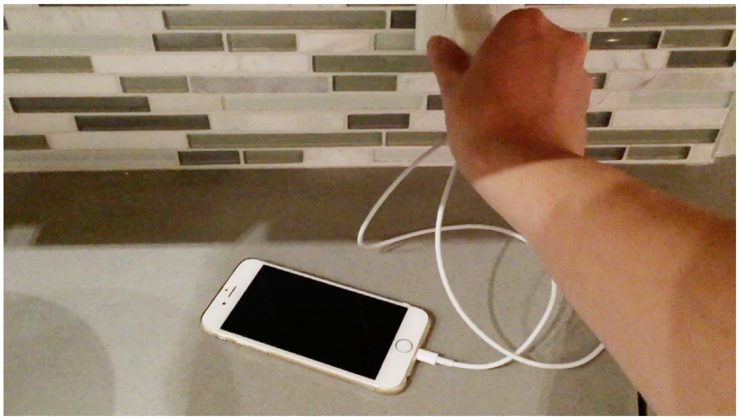
Participant interpretation:

"The wall socket is actually something that can dispense water, and the box is filling with water."



Smartphone flow: The smartphone flow experiment included the action of plugging the smartphone into an electrical outlet, coupled with the sound of water flowing. A video of the experiment titled "Phone Plug" can be found at: http://www.dixonlo.com/work/experiential.html

Smartphone



Smartphone reflection

The action of plugging in the phone and the sound of water flow drove most respondents to understand the phone as charging. Unlike the wood block example, plugging the phone into an electrical outlet is part of the normal operation of the device, and layering a sound over the action only served to help identify the sound as representing flowing electricity.

However, a subset of respondents asked why the sound of water was used over a sound that was more electricity-like. When asked what that sound would be, responses ranged from a sound with a more static, buzzing quality, to ambient sounds from science fiction cinema.

Selected disconnect

Participant response:

"I know what you are trying to do, showing that electricity is transferring with the sound, but why did you use the sound of water and not of electricity?"

USB drive

USB drive flow: The USB drive flow experiment included the action of plugging the USB drive into a computer, coupled with the sound of water flowing. A video of the experiment titled "USB Plug" can be found at: http://www.dixonlo.com/work/experiential.html

USB drive reflection

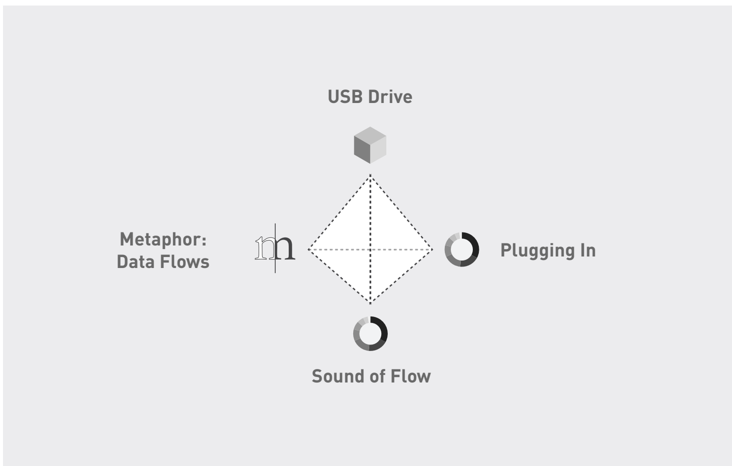
Most respondents were able to interpret the sound of water as representing data flow, while a single respondent thought the drive was charging. It was interesting to learn that a majority of respondents also inferred directionality from the sound, and thought data was travelling from the USB into the computer. A theory for this interpretation is that the sound of water flowing also carries an echo, indicating the size of the container the water was flowing into. The deeper and larger echo signified water was flowing into a large container, which would be the computer and not the drive.

Similar to the smartphone example, respondents asked why the sound was of water specifically, and not more data-like. When asked what flowing data sounded like, responses ranged from references to video games, to sounds previously heard on desktop computing systems, such as the "swish" sound certain email programs make when sending mail.

Participant interpretation:

"Data is flowing into the computer."

Selected interpretation



EXPERIMENT 7: SHAKE

The shake series of experiments tested whether respondents were able to link the sound of substance colliding to abstract processes within objects. Objects used in this experiment were a wood block, a debit card, and a USB drive. The wood block was assumed to have no underlying process, whereas augmentation to the debit card was intended to reflect financial information, and augmentation to the USB drive was intended to reflect data quantity and size.

Wood block shake: The wood block experiment coupled the action of shaking the wood block with the sound of a salt shaker being shaken, and a container of coins being shaken. Videos of the experiment titled "Wood Shake Large" and "Wood Shake Small" can be found at: http://www.dixonlo.com/work/experiential.html

Wood block

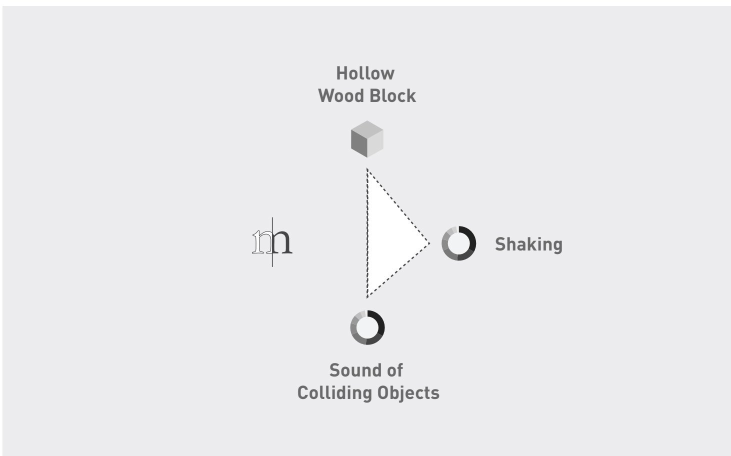
Wood block reflection

The close linkage between the augmentation and reality caused respondents to assume the wood block actually contained the items that were making the sound, even though it was only simulated.

Participant response:

"I don't see any special meaning, the wood block contains items that are being shaken."

Selected disconnect



Debit card shake: The debit card shake experiment coupled the action of shaking the debit card with the sound of a salt shaker being shaken, and a container of coins being shaken. Videos of the experiment titled "Debit Shake Large" and "Debit Shake Small" can be found at: http://www.dixonlo.com/work/experiential.html

Debit card

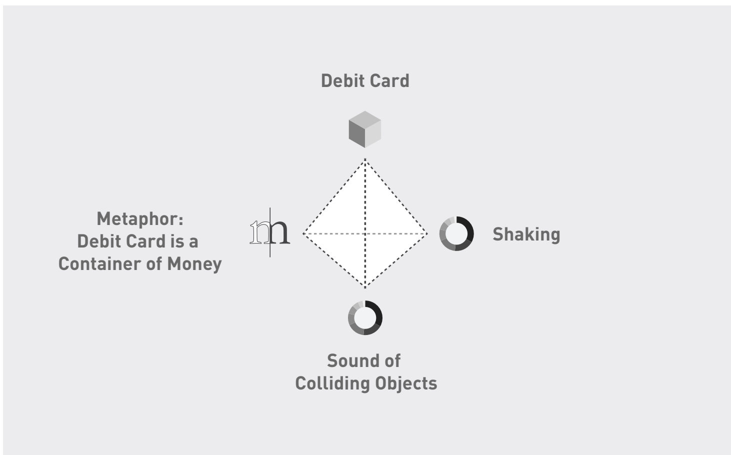
Debit card reflection

Though in previous examples, respondents had difficulty thinking of the debit card as a container of money, the coupled sound and action created different results. Respondents readily identified the heavier rattle as signifying more cash in the bank, and the softer rattle as less. The specificity of the sound of salt, and the sound of coins, however, confused some respondents. They asked why the sound was different quantities of different items, rather than different quantities of the same item.

Participant interpretation:

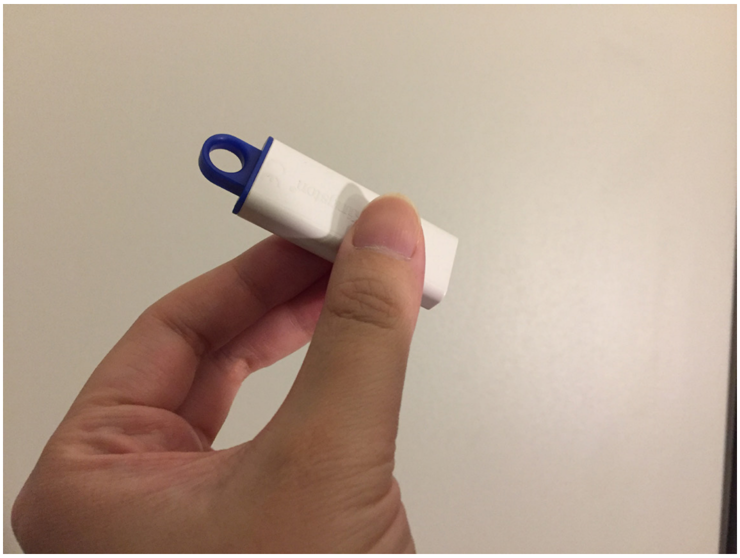
"I can hear how much money is in the card from the rattling sound."

Selected interpretation



USB drive

USB drive shake: The USB drive shake experiment coupled the action of shaking the USB drive with the sound of a salt shaker being shaken, and a container of coins being shaken. Videos of the experiment titled "USB Shake Large" and "USB Shake Small" can be found at: http://www.dixonlo.com/work/experiential.html



USB drive reflection

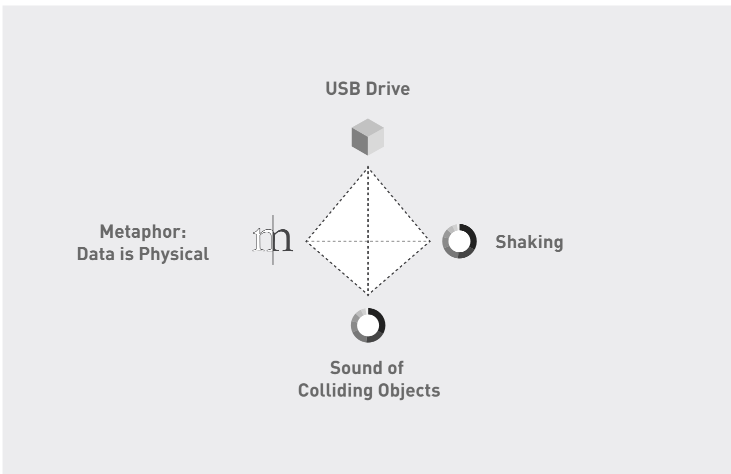
Respondents were able to identify the sounds as representing different quantities of data within the drive. However, they were not able to discern the size of the files from the sound. One respondent thought that the augmentation could be easily confused with a drive that was simply broken, and had moving parts inside.

Finally, respondents asked why the collision sound was not more data-like. When asked what the collision of data sounded like, responses ranged from references to video games, to sounds previously heard on desktop computing systems, such as the sound of a dial-up modem.

Selected interpretation

Participant interpretation:

"The sound tells me how much data is in the drive."



Chapter 4

DESIGN OBSERVATIONS AND RECOMMENDATIONS

GENERAL OBSERVATIONS ON OBJECT / TYPE OF MEANING / REPRESENTATION

Study of the experiments in the previous chapter resulted in a set of design observations and recommendations for those interested in augmenting objects in an experiential way.

OBJECT

Reflection on the mistake of thinking there is a blank object with no invisible processes, and the danger of targeting incorrect schema.

Originally, it was thought that objects with no invisible processes could be used as a control in testing. However, the way viewers interpreted the wood block in the experiments showed that this is not true. Sometimes, viewers identified the woodblock as a general "thing", without any specific identity and without an invisible side. For these viewers, the woodblock could have been replaced with any other general object, and their understanding of the experiment would not have changed. They also answered "I don't know" when asked about the meaning of augmentations. Other times however, viewers identified the wood block as something more specific. They saw it not as a general "thing", but as something that was to be used in construction, for example. When identified this way, the wood suddenly had an invisible attribute of sturdiness that needed to be made visible. Whenever possible, viewers who saw the wood as a construction material interpreted augmentations as explaining whether the wood was strong enough for that use.

When analyzing the study outcomes, sometimes respondents would identify wood as an abstract thing, and other times as a construction material. Some respondents would switch between definitions, depending on the type of augmentation used. This means that the respondents held various schemas of "wood", and would default to whichever definition the augmentation was most concretely linked. A piece of wood floating, for example, had no concrete link to any definitions of wood for most respondents, so they struggled to think of an invisible process that could be being represented. However, discoloration reminded respondents of the materiality of wood. Thus respondents were able to switch to a definition of wood as construction material, then interpret the wood losing color as an indicator of structural weakness.

In other words, the identification of an object as having no invisible process was actually an insufficient understanding of the schemas viewers carried for the object, and the failure of the augmentation to target these schemas.

Example:

An example of the difference between correct and incorrect targeting of schema can be seen in the debit card and USB drive experiments.

The original assumption was that since a debit card was a dispenser of money, people also think of them as containers of money. However, as explained by one respondent, a debit card was more a key to access money, than a container of it. Because of this, augmentations that tried to show weight change in cards to reflect the amount of money held inside failed. Given the viewer's schema of the debit card, there was no money inside the card to be represented through augmentation.

On the other hand, a USB drive was seen as a container of data. Thus augmentations that tried to give materiality to the invisible data in the drive were more successful.

REPRESENTATION

Reflection on factors governing the clarity and effectiveness of an augmentation.

Examples in this thesis made alterations to the visual appearance, malleability, sound, and weight of objects. There are many more aspects of an object, such as its texture, smell, or taste that could be tested, and they are being considered for future exploration. However, given the length of time of this study, the aforementioned attributes were determined to be good starting points for investigation.

Since this thesis focuses on finding experiential representations capable of delivering information on invisible processes within objects, most observations made were relative to the representation category. This section will be split into the following:

Observations on:

1. Believability
2. Positive vs Negative
3. Specificity
4. Overlap
5. Completeness
6. Imagining

Believability

In the color loss experiments, the color was taken from a discount card to give the feeling that it was old and expired. However, without being able to compare the card with the original colored version, respondents only saw a card that they believed was supposed to be black and white. This example shows the dangers of creating representations that are too normal or even executed too well. If the viewer believes the augmentation is part of reality, they will not see it as carrying any special meaning.

Positive vs negative

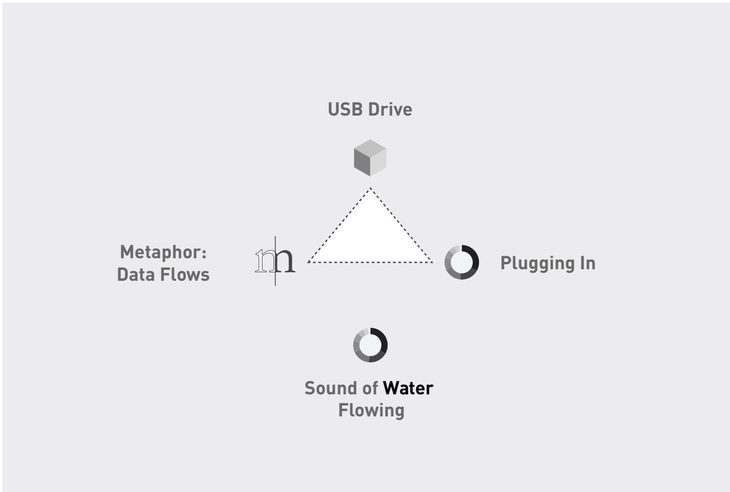
The USB drive weight alteration experiments demonstrate the difference augmentations that seem positive and those that seem negative. Positive alterations are more likely to be interpreted as simple notifications that stop viewers from looking for deeper metaphorical meaning. With the floating USB drive example, viewers interpreted the positively connotated act of floating as a notification that the drive wanted attention, without making the connection to data having weight. Whereas in the sinking USB drive example, the more negatively connotated act of sinking was not interpreted as an attention grabbing notification, which enabled respondents to look for a deeper metaphorical interpretation of data having weight.

Specificity

In the experiment where the action of plugging a USB drive into a computer was overlaid with the sound of water flowing, respondents understood that the water sound signified that data was being transferred. However, some respondents asked why the sound of water was used, and not the sound of data. This is a case of over-specificity in the design of the representation.

Participant response:

"I see that the sound is supposed to represent data flow, but why did you use the sound of water and not data?"



Under-specificity has the opposite effect. In the debit card experiments, the inability to link augmentations to money specifically caused respondents to struggle to interpret meaning.

Overlap

While respondents were unable to think of the debit card as a physical container of money in most experiments, this link was easily made in the example where the shaking of the debit card was paired with the sound of physical objects being shaken. As a result, it can be inferred that when there are multiple overlapping representations pointing to the same meaning, the viewer can be convinced to change their schema of the object.

Completeness

One reason why respondents could not see the USB floating as a reflection of lightness resulting from the lack of data it contained, was that the representation broke down when they extrapolated it's extremes. They asked, if the drive floats when it has less data, what would happen when it was completely empty, and shouldn't it float upward to infinity.

Imagining

In the USB drive data transfer experiment, the sound of water flowing was played over a plugged in USB drive. Even though data does not have a sound, respondents questioned why the sound of data itself was not used. Indicating that people have quite sensorially complete images of abstract things.

TYPES OF MEANING

Reflection on categorizing the meaning respondents found in the experiments.

Origin of the meaning categories

The possible categories of meaning used in the model were created for this thesis after reviewing experiment results. This means it is entirely possible there are categories that are missing or that future work will reveal that certain categories should be merged.

The categories used to structure test results were metaphor, personification, physical affordance, and simple notification.

The first two categories, metaphor and personification are simplifications of Lakoff and Johnson's metaphor categorizations from their work "Metaphors We Live By". Lakoff and Johnson's original metaphor categories were orientational, structural and ontological. However these categorizations sometimes overlapped. What's more, it was sometimes difficult to discern from survey responses whether respondents were interpreting metaphorical meaning from augmentations, or something simpler, like seeing the augmentation as eye catching, and therefore a simple notification. In order to not over attribute understanding on behalf of the respondent, a notification category was used for responses that did not explicitly demonstrate metaphorical understanding, and a metaphor category was used for those that did. In addition, Lakoff and Johnson's categorizations describe personification as a type of ontological metaphor. However for the study, personification was given its own category as it was a type of metaphor that appeared most often. Finally the affordance category was created when it was noticed that augmentations, especially those that altered the physical form of objects, were sometimes viewed as physical affordances.

Examples of categorizations of meaning for the experiential augmentation model

Notification: Responses that understood augmentation as calling attention to the object, but without a deeper metaphorical comparison. For example "the phone is becoming transparent to tell me it is switched off".

Physical affordance: Responses that understand augmentation by reading how physical qualities affect interaction. For example "the phone is fading out and becoming harder to find, so I don't use it as much."

Metaphor: Responses that demonstrate the linking of invisible processes to more concrete entities. For example "the USB drive is sinking, because the data inside is so heavy," demonstrates the linkage of data to a physical thing with weight.

Personification: A special application of metaphor that thinks of objects as living things. For example "the USB drive is sinking into the table to hide from me, so i don't use it."

Additional category "pop culture"

A small minority of responses in the survey pertained to an extra category of pop culture. Though there weren't enough examples of this type of response to warrant its own category, it may be useful for categorizing future expanded testing.

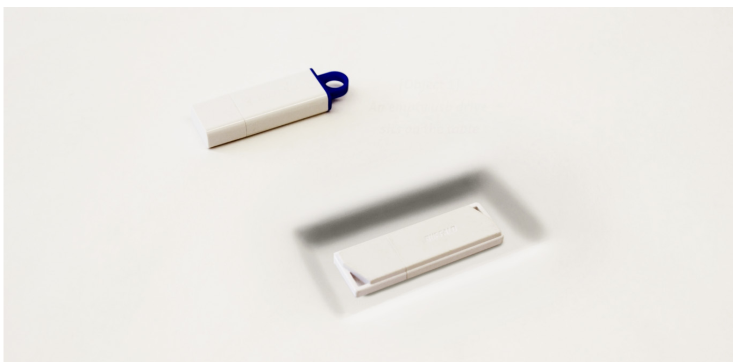
An example of pop culture would be referencing the depiction of time travel in movies to understand the fading out of objects. In time travel movies, altering an object's past will cause it to cease to exist in the present. This process is often depicted by the object slowly fading out in the present time. One respondent thought "the smartphone is fading away because someone has altered its past."

DESIGN RECOMMENDATIONS

Inability to interpret meaning from augmentation experiments in this thesis can be explained as the failure to draw a connection between two or more points in the experiential augmentation model. The following sections use the observations from the previous section to provide design recommendations to strengthen the connection between a viewer's understanding of object, representation and meaning.

IMPROVING UNDERSTANDING BETWEEN REPRESENTATION AND MEANING

Use understandable execution - The USB sinking representation was sometimes interpreted as the drive sitting in a hole in the table because of insufficient quality in execution. A better execution could leave less space between the drive and the table.



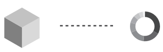
Make the representation a little unusual - If representations can logically appear in reality, viewers may interpret them as reality, and not realize they are an augmentation with underlying meaning. In the image to the left, expiry of the discount card should have been depicted with representations not possible in print media.

Make sure representations do not conflict with schemas of the object - In the example that played the sound of water flowing over a USB drive being plugged into a computer, respondents mentioned they did not like their electronics near water, and the sound made them uncomfortable. Thus the sound should have been changed to one more reminiscent of data.

When appropriate, use representations that have a slight negative meaning - Respondents often saw representations that have positive meaning, such as floating, or becoming more colorful, as a call for attention, and default to interpreting the representation as a simple notification rather than finding a deeper metaphorical connection. Negatively connotated representations, such as sinking or removing color did not yield this problem. Thus when deeper metaphorical interpretations are needed, negatively connotated representations have a higher chance to be successful.

Do not expect approaches to yield consistent results - Just because fading delivers the meaning of running out of power when applied to a smartphone does not mean that it will deliver the same meaning in a different electronic device. Thus with each augmentation, it is important to test for resulting interpretations.

IMPROVING UNDERSTANDING BETWEEN OBJECT AND REPRESENTATION



Check for completeness - Extrapolate the representation/meaning combination to its extremes to ensure they work. As previously mentioned, in the USB floating example, respondents were told at the end of the experiment that the intention was to depict a drive that was light because it was not carrying much data. They then questioned what would happen if the drive was completely empty, would it float upward to infinity? Thus, a complete understanding of the underlying process to be represented is a prerequisite to designing an augmentation.

If unable to target a specific meaning, try to create coherence in meaning - In the USB sinking example, there were multiple interpretations of meaning:

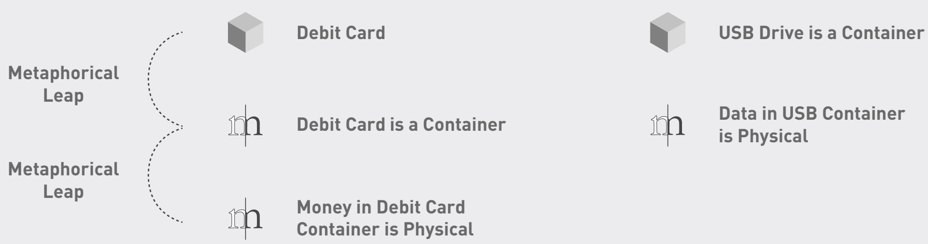
1. The USB drive is heavy with data
2. The USB drive is hiding from me
3. The USB drive is physically difficult to pick up, since it is in a hole in the table

All interpretations resulted in the same overall action—not to use the drive—and sometimes that may be enough for the designer's purposes.

Target the correct specificity - In the example that used water flowing as an indicator of data transfer, some respondents questioned why the sound was of water, and not of data. The better solution would be to tap the respondent's imagination for a representative sound of data, or to find a sound where they would not identify the substance that was flowing, but only that there was flow. When asked what this sound could be, respondents mentioned the swish sound sometimes heard when sending emails. A second iteration of the data flow experiment, can be seen here: http://www.dixonlo.com/work/experiential.html under the title "Data Pour".

IMPROVING UNDERSTANDING BETWEEN MEANING AND OBJECT

Target a lower metaphorical depth - In the debit card examples, it was assumed that the debit card was thought of as a container of money, and that the money it contained was thought of in a physical way. However for many respondents, the debit card was more of a key to access money than a container. What is more, respondents thought of the money that was accessed as a digital rather than physical thing. Linking a debit card's weight change to the idea of containing a lot of physical money actually required two metaphorical leaps. In contrast, linking weight change to the amount of data in a USB drive only required one metaphorical leap, respondents already thought of the drive as a container of data. Because of this, the second example was much more successful. Thus when creating augmentations, it can be useful to map out and reduce metaphorical depth as much as possible.



Chapter 5
CONCLUDING DISCUSSION

REFLECTION ON PROCESS

Scenario

During testing, respondents imagined themselves using the objects for a variety of purposes. These imaginary scenarios helped define the identity of the object. For example, sometimes a business card was received after a recent business meeting, and a loss of rigidity was an indicator of the trustworthiness of the giver. Other times the card was received further in the past, and the rigidity loss signed the card's information had become invalid. Without giving respondents a specific context, they were free to imagine a range of identities for the object. This allowed for the survey to uncover connections between various object / representation interpretations. However when doing future testing of experiential augmentations designed for a specific object and purpose, it may be useful to situate the test in a specific context and scenario in order to focus respondents on specific object / representation interpretations.

Learning

The current test was performed without giving respondents any background information. As respondents progressed through the study the number of examples where they could not interpret meaning decreased. Some later responses mentioned explicitly that they were beginning to see a pattern in what the experiments were "trying to do". Responses during the later portions of the survey were richer because of participant learning. On the one hand this is a positive signal that experiential augmentation is easily learned. On the other hand it points to the need to decide whether these augmentations are to be tested in a world where augmented reality is assumed to be common. In this case, participants should be primed about the context before testing in order to reduce learning time.

Cultural and age variations

The survey was taken by people from various cultures and ages. However the anonymous nature of the survey precluded any conclusions that could be drawn from these two variables. Some responses in the survey, especially those relating to the understanding of money and pop culture, could be both culturally and generationally specific. An example of variations in understanding is illustrated through the ease of imagining the money a debit card accesses as a physical object. Those who had difficulty grasping the concept may be used to the current credit-based spending culture in the United States, while previous generations in the US and other countries may have more physical cash based cultures. In other experiments, pop culture was referenced for meaning. The time travel movie "Back To The Future" uses the fading away of a character to indicate that their past has been altered. One respondent used this reference to interpret the fading out experiments. The referencing of film points to the influence of the way the fantastic is portrayed across generations and cultures. Finally, the metaphorical classifications used in the experiential augmentation model were based on an analysis of the English language. While all participants were fluent in English, their distinct cultural background may still affect their understanding of English metaphors. For future iterations of testing, more information should be gathered on the background of respondents to control for age and cultural differences.

Test grouping within the survey

In this second iteration, experiments were grouped by type of augmentation. For example, the first set of tests included three floating objects, the second included three sinking objects, and so on. A specific type of augmentation does not necessarily create the same meaning when applied to different objects. However, within each grouping of three, some respondents would reference earlier answers in their interpretations. If they had interpreted a fading piece of wood as being structurally unsound, their first inclination may be to interpret a fading debit card and smart phone as structurally broken. An improved test design may be to group tests by object rather than by augmentation.

CONCLUSION AND FUTURE WORK

This thesis began with a framing of experiential augmentation, which is the use of experiential and qualitative representations to augment real world objects, in the future context of ubiquitous computing. The purpose of experiential augmentation is to meet two challenges facing the design of computing that is embedded in our environment. The first is the need for objects to communicate their invisible processes, without the aid of traditional screens. The second is for this communication to be intuitive enough that it can be understood "without too much effort or with the background of attention" (Offenhuber 293).

MEETING THE CHALLENGE OF INVISIBILITY

Regarding meeting the challenge of explaining invisible processes in objects, the experiments showed that experiential augmentation is effective in delivering information at a range of specificity and richness. Though originally the augmentations were targeted at explaining an invisible process within objects, test responses indicated that experiential augmentation has the potential to be used to give visibility to two other aspects of an object, object type, and extended functionality. These are detailed in the next sections.

Visibility of invisible process

Representing invisible processes is the main aim of experiential augmentation. Experimentation has shown if not designed correctly, a single representation can lead to multiple interpretations of underlying process, or to confusion. However, when designed well, a representation can create intuitive understanding of the invisible processes conducted by objects. Analysis of experiment findings revealed that intuitive understanding of representations results from a fit between three aspects of the augmented object. These aspects are the participant's subjective understanding of the object, subjective experience of the representation, and the category of metaphor/meaning the participant is inclined to use as a lens for interpretation. Having identified the three building blocks that lead to the understanding of an experiential augmentation, this work then focuses on analyzing how a better fit between each of the three blocks can be created and the benefits of such strong fits. As a result of this inquiry, a set of design recommendations for those interested in augmenting objects in a similar fashion is proposed. Overall, experiential augmentation has shown that augmented reality can be used in an experiential fashion, to deliver information about objects.

Visibility of object type

Test responses have shown that augmentations are able to change the participant's understanding of an object. An example of this theory is illustrated in the initial difficulty of some respondents to view the debit card as a container of physical currency. To them, the card was a key with which digital currency could be accessed. However, their view changed in one of the later experiments depicted the shaking of a debit card coupled with the sound of money rattling in a container. In this example, a majority of respondents were able to imagine the card as a container. This shows that aside from illuminating processes within objects, experiential augmentations are able to help define objects themselves.

The ability of augmentations to define objects is useful when the objects themselves are unfamiliar. An example would be the use of the money making a rattling sound to differentiate an RFID cash card (used in some countries such as Japan to pay for public transportation) from a credit card. Though both are plastic cards that are used for payment, a credit card accumulates debt with each use, while the cash card contains a balance that is depleted. Because the RFID card fits the model of money container, and a credit card does not, someone accustomed to credit cards, and new to the RFID card could receive indicators on the difference just from the sound the card makes.

Visibility of unexplained extended functionality

Experiential augmentation can also help explain unfamiliar functionality. In one of the experiments, the sound of water was played over the action of plugging in a USB memory drive, with the intention of using the sound to illustrate the transfer of data. Participants responded that hearing the sound of water while operating an electronic device made them nervous. This shows the ability of an augmentation to carry the schema of other objects, in this case of water. What is more, the schema not only includes the materiality of water (as a substance that can disrupt electronics), but also the interactions possible with water. When asked what other interactions may be possible with the augmented USB drive, respondents mentioned that the action of pouring out the drive when it was not connected to a computer could be used to delete the information inside it. The interaction patterns possible with water had been mapped onto the data in the USB drive. This shows how experiential augmentation can not only be used to deliver information about the object, but teach previously unknown interaction patterns possible with the object.

Future work with visibility

While the experiential augmentation model is useful for classifying results, and the design recommendations are useful for redesigning objects for which testing has already been done, methods directed at aiding those interested in creating augmentations for testing do not yet exist. This thesis has focused on creating a wide range of experiments to understand participant reaction to different design choices. However, those interested in using experiential augmentation may be more focused on specific use cases. Future research will be directed at developing methods for translating specific objects, contexts, and scenarios into appropriate representations.

Additional testing is needed that explores the potential for experiential augmentation to help explain both the functionality of unfamiliar objects, and the unfamiliar functionality in known objects. Finally, while this thesis has experimented with representing one invisible process within an object, it has not tested the use of multiple augmentations to explain separate hidden processes.

MEETING THE CHALLENGE OF CALMNESS

This thesis defines calmness as a level of intuitivity and a lack of attention hungriness, that allows an object to fade to the background of attention. While our familiarity with the physical world allows most objects in our environment to do this, it is possible, as Keiichi Matsuda's video Hyper-Reality shows, to augment objects in such a way that they continuously call for attention. The hypothesis in this thesis was that indexical visualization-based representations would be more intuitively familiar to viewers than overlaid screens of symbols and icons. The familiarity of these representations would allow objects to communicate their invisible processes in a calm fashion. Practically, the calmness of an augmentation was difficult to measure, especially as interpreting the behavior of augmented objects represented a new experience for all participants. A novel representation naturally required more interpretation than a familiar one. The potential for calmness, however, can be inferred by participant responses.

Learnability

The survey allowed for respondents to answer "I don't know" when unable to interpret an augmentation. As backgrounds and contexts were not provided, the first few experiment sets featured a fair number of “I don’t know” responses. These declined significantly as the survey progressed. Even without prior understanding of indexical visualization, respondents were able to learn from the pattern of questioning, and give progressively richer explanations of augmentations than when they were seeing them for the first time. While this may illustrate a weakness in the survey method, it also shows that once the overall cause and effect nature of indexical visualization was learned, participants could apply it to unfamiliar objects and augmentations without need for extra explanation. This would be an example of Weiser’s comment that, “Whenever people learn something sufficiently well, they cease to be aware of it” (Weiser, “The Computer” 1). Once the interpretation of experiential augmentation is sufficiently learned to become a calm process, augmentations can be applied to unfamiliar objects, and process will remain calm.

Holism

Part of the calmness of experiential augmentation comes from the augmentation being seen as a characteristic or property of the object. An augmentation that is seen as separate or overlaid on top an object, is essentially a new object added to the space. If, for each object with an invisible property, we needed to create a separate object to explain the property, we would be doubling the amount of objects in our environment fighting for attention. When well designed, participants in the survey did not refer to the augmentations, but only to the object performing a behavior. For example, they referred to USB memory drives as floating and smartphones as becoming transparent. When not well designed, the augmentation stood out like a separate phenomena. In the experiment where the sound of water flow signified transference of data, a few respondents commented that the sound seemed disconnected from the object. A well designed experiential augmentation is able to embed itself as part of an object, becoming just one of many physical qualities of the object.

Too calm

During testing, a complaint arose that some examples were too easily overlooked to serve as effective notifications. A discarded experiment featured a smartphone which had colors that grew in saturation as an indicator of gaining charge. The experiment was not included in the final set because initial feedback complained that the difference in color could only be seen if someone was specifically looking for it. The experiment was later updated to the loss of opacity, as opacity change was a more forceful representation that affected not only color but the entire existence of the object. While the quieter, calmer representation of saturation was not used in tests, the option to do so shows that experiential augmentation allows for a range of attention hungriness.

Future work with calmness

This thesis was only able to test single objects for interpretations of augmentation. However experiential augmentation is envisioned for a future world of ubiquitous computing, where various objects in the environment will be augmented. A better test of calmness would involve a set of objects, placed in context. Similar to the direction of future work for invisibility, further experiments in calmness should include a scenario in which a plausible set of augmented objects could inhabit.

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