This dissertation introduces a framework for ecological and cognitive processes of meaning attribution to product forms. The literature of perception, product experience and human-product interaction is reviewed and overarching theoretical perspectives on these topics are discussed. The theory of perception and sensation and three major complementary theories - affordances, product semantics and emotions - are then presented in order to apprehend connotations of meaning that these theories advocate. The framework suggests that physical and perceptual qualities of the product forms co-exist. These qualities trigger user’s attention, concerns, memories, and knowledge within different levels of contexts, and lead to meaning development in user’s end. The designer, as a form-giver and meaning attributer manipulates product form considering conditions such as business goals, and manufacturing. The design process is denoted in order to represent meaning attribution within the process. The framework provides holistic view and may provide better understanding of the meaning attribution process to product forms. It advocates design practice and research to design for meaning. Extending the framework, the current dissertation explores the relationship between how people understand the meaning of an object (e.g. safe, elegant, high-tech look) based on its physical features (roundness in multiple dimensions). A mixed method approach to understanding the meaning attribution process for product form is investigated in a set of experiments. Participants in experiment one interacted with nine basic geometric objects while participants experienced nine hard drive and nine soap dispenser forms in experiment two. The roundness of object corners were altered from
crisp 90 degree edges to blunt round edges along 2- and 3-dimensions. A survey captured rankings of meanings for each object, and interviews explored meaning attribution strategies of the participants. Results suggest the involvement of both bottom-up and top-down approaches in participants’ meaning attribution process depending on the meaning of interest. Moreover, the data suggests that a very small change in roundness of the form lead to large impacts on meaning (suggesting a quadratic relationship). Finally, results indicate a connection between central and complicated meanings.
Meaning Attribution Model of Product Forms: A Holistic Approach

by

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DEDICATION

To my wife, Zeynep, for her patience and love, to my family and all friends, for their support and to inventers of raki, yogurt and macaroni (pasta).
BIOGRAPHY

Engin Kapkin received a Master of Science in Industrial Design Degree from Anadolu University, Graduate School of Science in Turkey in which he concentrated on design education and writing design brief. He earned Master in Industrial Design degree from North Carolina State University, College of Design as a Fulbright Scholar where he focused on design and research on electricity monitoring systems in residential settings. He has been a faculty member at Anadolu University, Faculty of Architecture and Design, and actively assisted and taught classes at North Carolina State University, Department of Graphic and Industrial Design where he pursued his Ph.D. in Design degree. Kapkin engaged several research projects and organizations of design events during his fellowship at Research in Ergonomics and Design Laboratory (REDLab) at North Carolina State University. He worked and interned at local craft centers, T-Design office, and the Ford truck factory in Turkey; interned at IDEO Palo Alto CA office; and have worked with dxlab design in Raleigh NC. He focuses on topics of industrial design, product design, design education and design research, creativity, human-product interaction and experience design, and product form development processes. His diverse interest converges on three major themes: design practice, education, and research.
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INTRODUCTION

It does not matter how much you know, things you tell is limited to what others perceive.
“...ne kadar bilirsen bil, anlattıkların karşısında anlayabilğini kadarıdır.”
Mevlânâ Celaleddin-i Rumi

There are many instances in which individuals can recall their frustrations with using a product. A user may recall negative experiences, such as being unable to open a box, choosing the wrong program to wash clothes and losing a favorite shirt, or even cutting fingers on plastic packaging. In contrast, there are also many surprising moments that a user may recall, seeing someone using a product in a different way that makes its use very easy, looking at a hovering chair, appreciating a simple detail that helps us deal with a problem, or wearing something that makes us feel happy or confident. To expand the examples to different scenarios, a user may consider their grandfather’s fountain pen that was inherited, or a cellphone forgotten and left at home then feeling its absence. The examples may expand including a situation in which a user faces a brand new product, but somehow knows how to use it instinctively. In this case, the product interface means something to the person and helps them to understand how to operate it. The positive experience of easy-use may then construct a meaning. A slightly different example can be found, when a user desires a product because their singer idol owns it or the product fits the persona. In this case, the product becomes a medium to becoming the idol and represents the meaning of the idol’s persona. Conversely, a user may avoid using a product since they think the product represents a certain persona or gender that does not suit them. Last but not least, a user may prefer one product to another (both of which functions the same) due to its appearance since the user may think the product fits their environment better or just looks elegant. These products are not only sustaining their values with physical durability, but also with meanings with which they were embedded.

The experience is positive or negative; it is evident that someone designs these products for a specific user or user group. One question is why some products result in positive experiences, while some others do not. The designers’ role is to organize the relationship
between users and products, and generate better products so as to eliminate misinterpretations of product-use and generate positive experiences. In order to do so, designers should understand the user’s needs, requests, and desires; how they prefer to operate things; and how they assign meaning to products. Intensive interactions between designer, user and the product become essential to learn about these requirements and gain information.

1.1 Significance of Current Investigation and the Problem Area

The requirements and expectations from a product has moved far from the functionalist way of designing products (You & Chen; 2007). Users expect that a product should already be functional and have high usability at the onset; therefore, experiencing a functional and highly usable product is not surprising. However, it is not satisfactory or acceptable when a product is difficult to use (Jordan, 2000). Similarly, Krippendorff (1989) states, “The slogan ‘form follows function’ thus implies abstracting the ordinary (scientifically naive, non-engineering-trained) user out of the equation and discarding the meanings that users construct and see”. According to Desmet and Hekkert (2007), these meanings along with aesthetics lead to an emotional experience of a product; and therefore, they are significant. In order to build these experiences, users should interact with the product over time, multiple exposures (Csikszentmihalyi & Eugene, 1981; Norman, 2004). There are many conceptual models and theories proposed to describe human-product interaction; however, these models have mostly focused on Gibson’s Affordance Theory (Gibson, 1977), the basic communication model of Product Semantics (Krippendorff & Butter, 1984), or the Product Emotion model (Desmet & Hekkert, 2002). The main promise of these models, in a very broad sense, relies on either a bottom-up perceptual approach, where it is believed that the physical qualities of the product drive the perception, or a top-down perceptual approach in which high level cognitive processes are believed to establish perceptual, subjective qualities of the product. Although both approaches are well known and commonly accepted, there are very few studies that examine the bottom-up and top-down approaches, simultaneously.

Except for Product Semantics, these models are commonly limited to interactions between the product and user. Despite the importance of the two-way interaction between the product and user, it is also important to consider designers and their concerns when designing
meaningful products. Designers were considered to be primarily a form-giver who shapes the appearance of the product. However, this is not the case in this era. Contemporary designers focus on many aspects of a product including appearance, usability, and the end-to-end experience. By doing so, they not only construct meaning around a product, they also actively receive, deliver and re-construct the meaning (Kazmierczak, 2003). However, the process of attributing meaning on the product forms from designer’s end is not yet clear. Designers have gained a deep understanding of how to manipulate physical qualities of a product, such as form, shape, size, and texture, throughout their educational and professional experiences. This may be considered a major skill set of a designer that helps them to build a product. However, this skill is not enough to design a product without the knowledge of how a user would interpret a certain form or shape, with a certain size, texture and material, and eventually what the product may mean to them as a whole. This set of knowledge for the designer might be an important key to designing meaningful products. Hence, studies which focus on the designer, product and user interaction as a whole and consider the designer’s application of product form and meaning attribution processes are needed.

Companies have recognized that positive experiences are key to the success of a product, while a negative experience guarantees dissatisfaction with a product (Kuniavsky, 2003). According to Davis (2008a, 2008b), contemporary design problems that designers attend to are not at the level of artifacts but more so at level of systems and experiences. Many suggest that designing experiences around a product begins from the abstract idea of the product to every single touch point that users interacts with product, in other word, the entire product life cycle (Cascio, 2013; Norton & Pine, 2013; Paquin, 2013; Rawson, et al., 2013). Therefore, it is essential to consider the meaning attribution process of product forms throughout the product development process. However, there are limited studies holding a holistic view of the development process in terms of meaning development.

Finally, it is expected that every year companies release new product lines with new form factors. The intention is that the new form factor reflects their achievement in technology and crafting (see Figure 1). However, the product form is more than a product enclosure. It signifies functionality and utility, evokes emotions, and it is a communication medium in social context. While product form has both a physical quality and mental-construct (Erlhoff
& Marshall, 2007), any small manipulation in product form might influence the users’ perception and might cause misinterpretations. Despite a considerable number of studies on affordances, product experience and emotions, the relationship between physical qualities of product form and meaning development is not yet completely understood. The current investigation offers a descriptive and holistic model of the meaning attribution process of the designer-product-user interactions focusing on the product form. This investigation suggests that meaning attribution processes occur throughout and after the product development process, and it values a three-way, designer-product-user interaction within the context. It also explores bottom-up (ecological) and top-down (cognitive) perceptual approaches when users attribute meaning on the product forms.

1.2 Outline of the Current investigation

The first chapter of this dissertation briefly introduces the problem domain and the significance of the investigation. Next, the purpose statement and overarching research questions are introduced along with a brief overview of the conceptual framework of the study. The major research question is represented in the conceptual framework. The second chapter includes theoretical perspectives upon which this dissertation is built and introduces

Figure 1 Different Generations of the same smart phone model. Form left to right oldest to newest model. Product form changes drastically. Advertisements of these phones promote the advanced technology that the company used when producing these phones (e.g diamond cut chamfered corners).
relevant literature that is briefly illustrated in literature review map (see Figure 2). The proposed framework acknowledges Affordance Theory, Product Semantics and Product Emotions as well as many studies focused on sensorial experiences, form development and cognition of designing. Thus, the conceptual Framework of Meaning Attribution to Product Forms (FMAP) will be constructed in detail in Chapter 2. Based upon this framework, research questions (see section 1.3) were developed which were addressed through two experiments. The third chapter introduces these two experiments that explore the relationship between how people understand the meaning of an object based on its physical qualities (e.g. roundness in multiple dimensions). The last chapter summarizes major findings of the dissertation; provides recommendations for design for meaning; and contains discussions and suggestions for future areas of study that may benefit from FMAP.

The dissertation is structured in a journal paper format. The intention is to submit the first chapter as one journal article. Experiments one and two are intended to be split into a pair of related but separate journal articles. Therefore, there are a few redundancies in these chapters.

1.3 Purpose Statement and Research Questions
This is a study about ‘design for meaning’. The purpose of this dissertation is, primarily, to investigate the relationships between product form and meanings through quantitative and qualitative research strategies. It is believed that the results may assist in generating meaningful products and human-product interactions. The investigation focuses on one main research questions. It questions the coexistence or complete separation between meaning (perceptual qualities) and product form (physical qualities) that ecological and constructivist (bottom-up or top-down perception theories) suggest. The sub-research questions address the development of a set of strategies based on the information from first and second experiments. The set of research questions are:
**RQ: How do the physical qualities of product form effect the user’s meaning attribution process?**

- How can we describe the relationship between the physical qualities of product form effect the user’s meaning attribution process? (Experiment 1 & 2)
- What is the role of gender, age, and occupation (designer/non-designer) when users attribute meaning on product forms? (Experiment 1 & 2)
- What is the meaning of meanings? And how can we organize them regarding the rankings they received from users? (Experiment 1 & 2)
- What the strategies do users prefer when attributing meaning on product forms? (Experiment 2)

**1.4 Conceptual Framework**

Product Semantics is the fundamental basis of the proposed conceptual Framework of Meaning Attribution to Product Forms (FMAP) (see Figure 3). According to FMAP a designer has intentions, which mainly drive the physical manipulation of the product. The product then contains certain physical and perceptual qualities. The user then makes sense of
these qualities and attributes meaning to the product. The major research question (RQ) of the dissertation explores the relationship between the physical manipulation of product form and the meaning generated related to it. Details of the conceptual framework will be introduced and discussed in chapter two.

1.5 Definition of Key Terms

*Product* is used interchanging with the terms stimulus and object. It refers to items crafted, manufactured and produced for sale. It is a physical entity rather than a service or digital application. Product is used referring to product form.

*Physical qualities of product* refer to form, shape, size, color, material and texture etc. In the case of first and second experiments, it refers to roundness of the edges of the objects and prototypes.

*Perceptual (subjective) qualities of product* refer to subjective ideas or attributed meanings about the product form.

*Designer*, also presented as a sender or form-giver, is the person who plans, generates ideas and makes things before it is produced or manufactured.
User is a person who perceives (perceiver), uses, and operates products that were designed and sold. User is also defined as a receiver of the message embedded in products.

Concerns refer to ideas that the user recalls or brings to situation. Concerns can be rooted in the users’ prior knowledge, experience, memories, desires, or future plans. Concerns may also refer to the perceptual, subjective qualities of products.

Attention (or attention tendencies) are the set of features that fulfill users’ needs, requests and concerns. Attention tendencies also refer to physical qualities of product forms, such as color; whereas, sometimes it is a perceptual quality that takes users’ attention.

Intentions refer to a mental image of an idea, a plan of work, or goal to achieve. It is the action plan or idea for solving particular problem. Intentions can be driven by designer’s observations and/or experiences and projected as users’ expectations or preferences.

Conditions have to connotations. In users’ end, the term refers to user’s concerns (needs, desires etc.). In designers’ end it refers to dynamics of market place and regulations around the product. Business goals, brand values and identity can also be considered as conditions. Constrains such as, material selection, production methods, technology and cost are also conditions that a designer considers when manipulating product forms.
MEANING ATTRIBUTION TO PRODUCT FORMS: A FRAMEWORK

Abstract: This paper proposes a framework of meaning attribution to product forms. The literature on perception, product experience and human-product interaction is reviewed and overarching theoretical perspectives on these topics are discussed. The theory of perception and sensation and three major complementary theories - affordances, product semantics and emotions - are then presented in order to explain what these theories advocate. The framework suggests that physical and perceptual qualities of the product forms co-exist. These qualities trigger users’ attention, concerns, memories, and knowledge in context, and lead to meaning development from the user’s end. The designer, as a form-giver and meaning attributer, manipulates product form considering their intentions and conditions such as business goals and manufacturing. The design process is discussed in order to clarify meaning attribution within the product development process. The framework provides a holistic view in order to provide a better understanding of the meaning attribution process to product forms. The framework may be used in design practice and research to design for meaning.

Keywords: Meaning Attribution, Emotional Design, Affordances, Product Semantics, Product Interaction, Perception of product meaning.

2.1 Introduction

Designers have gained a deep understanding of how to manipulate physical qualities of a product, such as form, shape, size, and texture, throughout their educational and professional experiences. This may be considered a major skill set of a designer that helps them to build a product. However, these skills are not enough to design a product without the knowledge of how a user would interpret a certain product form, physical interface (in certain size, texture and material), and eventually knowledge of what the product may mean to users. This knowledge for the designer is key to designing meaningful products. Hence, the human-product interaction has been extensively studied. Researchers have investigated the affordances of products (Gibson, 1986, 1977; Krippendorff, 1989; Norman, 1990; You & Chen, 2007), the semantic features of products (Butter, 2012; Hsiao & Chen, 1997; Krippendorff & Butter, 1984; Krippendorff, 1989; You & Chen, 2007), sensorial aspects of product experience (Gibson, 1962; Heller, 1982; Karana et al., 2009; Klatzky et al., 1993;
Lenay, 2010; Schifferstein, 2006; Dagman et al., 2010; Fenko et al., 2011), emotional elicitation associated with the product and its use (Sanders, 1992; Jordan, 2000; Desmet, 2003; Norman, 2004; Hekkert, 2006), and underlying cognitive processes and human-product interactions (Khalid & Helander, 2004; Cupchik & Hilscher, 2007; Desmet & Hekkert, 2007; Crilly et al., 2009; Karapanos et al., 2009; Locher et al., 2010; Schifferstein & Hekkert, 2007; Schifferstein, 2010; Pucillo & Cascini, 2014). The major theoretical perspectives of these studies, in a very broad sense, relies on either a bottom-up perceptual approach, where the physical qualities of the product drive the user’s perception, or a top-down perceptual approach in which cognitive processes (such as knowledge acquisition and prior experience) are believed to establish subjective qualities of the product. Although both approaches are well known and commonly accepted, there are very few studies that examine the bottom-up and top-down approaches, simultaneously. Moreover, despite the importance of the two-way interaction between the product and user, few studies consider the designer investing conscious effort to embed meaning in a product and their manipulation of the product form as a medium of communication (a three-way interaction designer, product and user). Furthermore, there is a large body of work concentrating on new product development, design processes, and design thinking (Brown, 2009; Cross, 1982, 2000; Groot, 1969; Kelley & Littman, 2005; Lawson, 2005; Mital et al., 1989; Razzouk & Shute, 2012; Roozenburg & Eekels, 1995; Rowe & Brown, 2008; Ulrich & Eppinger, 2011). However, apart from an exceptional study by Boess and Kanis (2008), there are limited studies considering the meaning attribution processes of users within the product development process in order to establish proper product experience. Hence, a study focusing on the designer, product and user interaction within the design process might expand our understanding of the meaning attribution processes of product forms.

The need for a framework of design for meaning has been described in previous studies. Krippendorff and Butter (1984) and Monö (1997) applied Shannon’s (1948) basic model of communication to product design to describe product form and meaning. Bloch (1995) proposed a model to investigate customers’ responses to product form. Crilly, et.al. (2004) propose a model solely upon literature reviews and interviews with designers. Based on human-product-designer interaction literature, the current investigation contends that a
holistic view on meaning attribution processes occurs throughout and after the product development process. This requires a brief review of theoretical perspectives on perception and sensorial product experience, affordances, product semantics, and emotions as well as the design process and design cognition. After the review of the theoretical perspectives, a conceptual framework of meaning attribution process of product forms (FMAP) is presented.

2.2 Assumptions and Theoretical Perspectives

Before addressing the theoretical perspectives in which this study is positioned, it is essential to discuss the ontological and epistemological assumptions of theoretical perspectives in general. Guba and Lincoln (1998) determine that epistemology seeks answers to the question: “What is the nature of the relationship between the knower or would-be knower and what can be known?” They state that the answer to this question is constrained by the answer given to the ontological question, which is “What is the form and the nature of the reality and what is there that can be known about it?” (Guba & Lincoln, 1998). Patton (2002) explains that there is not a stable and individual reality. He remarks the idea of our understandings are influenced by context and developed through interactions and among constructors (Patton, 1990).

Theoretical perspectives in general are discussed according to their assumptions on matters of human, environment and their relationship. Some of those perspectives are generally inherited from the Cartesian tradition, which approaches that ‘the mind’ and ‘the world’ as two different matters rather than one (Heft, 2003). According to Heft (2005), “even if psychology appropriates physical sciences because they both share the common criteria of objectivity, physicalist framework is not enough to convey qualities of psychological experience.” Ecological psychology is a school of thought that tries to convey the answer to this problem. It rejects the Cartesian tradition of dualism and brings a holistic approach to looking at the mind and human as a whole.

The term ‘ecological’ is based on Gibson’s (1986, 1977) approach of perception, which differentiates itself from the traditional perception theory that conveys the patterns of the stimulation on the sensory receptors. The primary focus of the traditional theory is that the stationary perceiver is positioned at a fixed observation point; whereas, the ecological

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1 Heft means disciplines, which share dualistic approach about the mind and human.
approach of perceiving focuses on dynamic perceiver-environment relationship. Because the conditions of the environment are not static (i.e. it changes over time), perceiving continues and involves exploratory actions of the individual in the detection of stimulus information (Mace & Heft, 2009). Consequently, the main epistemological assumption of ecological psychology is the transactional knowledge occurring in between animals and their environment. The ontological position of ecological psychology, may not be separable from epistemology, is that the reality exists in the intersection between animals and the environment.

The current investigation also holds a constructivist approach. Creswell (2009) states that according to constructivist view “individuals develop subjective meanings of their experiences – meanings directed toward certain object and things”. This approach accounts for the complexity of subjective experiences. According to Grotty (1998), the constructivist approach assumes that meanings are constructed by individuals while they engage with the environment. Individuals rely on their social and historical background when they make sense of the world and therefore, basic and initial meaning generation is both social and cultural. Both ecological and constructivist approaches suggest that meaning and knowledge are constructed in the mind, which is shaped by the context.

Ecological psychology and constructivism share mutual and yet still separable assumptions. First, they both emphasize the value of context in knowledge and meaning attribution. In an ecological approach, context is the environment and what exists in the environment; these two are not separable. It refers to physical qualities and what these qualities tell to users. Since the ecological approach is data-driven, the interpretation of the context may not require high-level cognitive processes. On the other hand, according to the constructivist approach the term ‘context’ is the social and cultural interactions that one has with world. It may refer to symbolic meanings and emotional reactions that a person learns or generates about the environment. It appears that the definition of the term ‘context’ may differ depending on assumptions. Moreover, both ecological and constructivist approaches are interested in the ‘meaning’ that individuals either gain or construct from their interaction with artifacts and environment. A question arises since there is limited explanation in both approaches: what do they mean by ‘meaning’ and ‘context’?
In the field of design, a considerable amount of research has been generated to guide designers to build meaningful products. However, apart from one theoretical discussion on aesthetics and affordances (Xenakis and Arnellos (2013), there are limited investigations that consider merging and relating these two approaches (ecological and constructivist) and investigate the overarching meaning attribution process. The current investigation holds a position across both ecological and constructivist approaches providing a holistic view by proposing that there is an overlapping ground where meaning attribution on product form may occur (Figure 4).

### 2.2.1 Bottom-Up and Top-Down Theories of Perception

Sternberg (2008) suggests that there are two major categories (Bottom-Up and Top-Down) for the theory of perception. “Bottom-up” theories, which value information gained from stimulus (products) claims that perception is driven by sensorial data of stimulus and therefore perception requires low-level cognitive involvement. These theories claim that perception is a
pattern recognition process of matching received information with those stored. The debate opposing bottom-up theories (Template Theory, Prototype Theory, Feature Theory, Structural-Description Theory) is that they lack explanation of the effects of expectations, knowledge, and prior experience on perception. On the other hand, theories driven by high-level cognitive processes, which account for these effects, are named “top-down” theories. In this case, sensorial data is perceptual stimuli that can be interpreted by top-down cognition processes. In other words, sensorial information becomes a structure to build perception through stored information. This is considered as a ‘constructive approach’ since the perceiver is believed to construct cognitive understanding from stimuli. The constructive perception includes three phases, “what we sense (sensorial information, stimuli), what we know (knowledge, expectations, experiences and memory), and what we can infer (using high-level cognitive processes)” in order to act accordingly (Sternberg, 2008).

According to Goldstein (2009) the process of perception is a sequential process that works simultaneously to establish an experience and responds to the stimuli. The perceptual process includes four categories (see Figure 5). Stimulus is the entity, which triggers the sensorial receptors. It refers to a physical quality in the environment, as well as its representation on the receptors. There are two aspects of stimulus. ‘The environmental stimuli’ refers to everything that has potential to be perceived in the environment, whereas ‘attended stimuli’ refers to things a person focuses its attention on. When stimulus is captured, the representation of it is formed on the receptors, and then transduced into an electrical signal. Electricity, as a second category in the perceptual process, refers to the electrical signal that is transduced by the receptors and transmits to certain areas of the brain. The electrical signal transforms into perception in the brain. The third category, Experience and Action refers to cognitive processes of perception. This is a conscious sensorial experience where recognition is the ability to identify, categorize and attribute initial meanings, and actions is the motor activities that response to stimuli. Goldstein (2009) suggests that actions are important behavioral outcomes of perception, and emphasizes that perception leads to actions. Knowledge, as the last category in the perceptual process, refers to information that the perceiver recalls about the situation. The knowledge may be our previous experiences with similar situations or stimuli. Correspondingly, Coren et al. (2004) defines the perceptual
processes as a whole process of identification and interpretation of the stimulus. He uses the term ‘information processing’ referring to how one captures the information from the environment, and processes it in order to produce perception, which then leads to actions. According to Coren et al. (2004), the information processing approach also begins with a ‘sensorial phase’ in which stimuli are registered on receptors. It is then followed by ‘interpretation’, which is the perceptual phase. Finally the ‘memory and cognitive processing’ engages. It is believed that interpretations though these processes are the subjective.

Product as a Stimuli: Sensorial Product Experience

The study of perception and sensation has diverse interpretations since the topic has been investigated in many domains. According to Coren et al. (2004), study of sensation focuses on the physical structure of the sensory organ and its reaction to physical stimulation. On the other hand, the study of perception is concerned more with how a person constructs conscious representation of environments as an experience based on the physical stimulation. It can be inferred that the study of sensation leads to identification of the stimulus where bottom-up cues and theories might apply, whereas perception refers to interpretation of stimuli in which top-down approaches are relevant for understanding.

There is a lack of explanation in the literature as to what sensorial product experience refers. Some studies considered the role of vision and touch in sensorial experience. In contrast to this definition of perception, Lenay (2010) suggests the sense of touch, including
haptic recognition, is an experience of perception. Gibson (1962) and Sonneveld (2010) mention an intentional, active or functional touch that occurs when a person consciously touches an object, and an unintentional, passive or non-functional touch that happens when an object touches an individual. Passive touch is a receptive sense stimulated when the perception is triggered by outside stimuli, whereas active touch is an explanatory sense prompted when an individual receives stimuli by touching something. Vision may be considered the most important and dominant sense. However, recent studies found that people may prefer one sense to another, depending on the nature of information that is sought (Heller, 1982; Klatzky et al., 1993; Klatzky et al., 1985; Schifferstein, 2006). In other words, the experience one seeks with the objects determines the preference of one sense over another.

Chen et al. (2009) investigated individuals’ perceptions of textures in relation to physical qualities within the context of confectionary packaging. A study by Zuo et al. (2004) provides evidence on how haptic sensory experiences influence individuals’ experience of materials and object. Hollins et al. (1993) investigates the subjective dimensions of tactile surface textures of different materials. Imamiya and Luo (2003) study the effects of colors on haptic perception of textured surfaces. Peck and Childers (2003) study how touch affects individuals’ purchasing decisions and emphasized the importance of research on haptic product experience in relation to shopper types. A study, which focuses on auditory qualities of products, noted that the noisiness of a product sound has a negative effect on ratings of product pleasantness (Fenko et al., 2011). Another study provides evidence of the potential effects of odor on product experience (Ludden & Schifferstein, 2009). In spite of the variety of studies on sensation and sensorial product experience the need for better sensorial product experience, and the necessity for related guidelines for designers have been reported in the literature (Dagman, Karlsson, & Wikström, 2010; Isaksson, 2007; Polanyi & Sen, 2009; Schifferstein & Hekkert, 2007), the role of sensation on meaning attribution on products has remained unclear and requires more work on both theoretical perspectives and application.

2.3 Product as a Functional Entity: Affordances

Moving the discussion focus from sensation to perception, the theory of affordances provides a rich perspective on meaning attribution. According to Gibson's (1986) direct
perception theory, that is also known as ecological psychology, the information from sensory receptors and contextual information are enough for perception to occur. Therefore according to the theory of affordances, a person does not need higher-level cognitive processes in order to transition from sensorial experiences and to perceptions. According to Gibson, a person uses and analyzes cues in the environment to relate, compare and find relationships between stimuli. Even though the stimulus in the receptor changes, there are invariant fixed qualities of stimuli such as physical size, form, shape or distance. These qualities called affordances are “…action possibilities afforded or available to observer…” (Coren et al., 2004).

In contrast to the perspective of affordances being associated with the object, Gibson (1986, 1977) indicates that affordances are all the possible behaviors that a person can act upon. Similarly, Krippendorff (1989) remarks that a person’s behaviors respond to the ‘product form’ and what a user expects from a product refers to the product’s ‘meaning’. According to Heft (2003), affordance refers to the features of the product that are meaningful for users. These features are not directly related to the product or user, but the relationship of the user-product system, in other words, this approach suggests that the meaning is the outcome of user-product interaction. The Affordance Theory offers that perceiving is detecting the meaning of the object, and the meaning of perception is the meaning of the object (Heft, 1988). Gibson’s affordance approach is based on the functionality of significant properties of an object for a perceiver. Affordance Theory suggests that the experience of perception is not only about the structure of objects or events in the environment, but also a person’s awareness of their functional features or meaning. Correspondingly, Gibson (2000) claims that affordances are not limited to physical qualities, but also include values and meanings. Gibson (2000) suggests that affordance can be time dependent since a person’s ability to manipulation and control environments/events may change throughout their life.

Norman (1990) emphasizes the importance of affordances in human-product interactions. According to Norman, affordances are “perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used (Norman, 1990).” According to Norman, a product should give appropriate feedback on its functions in order to establish better usability. If the affordance of a product matches with its real function and
is understandable for users, then the product will have better usability. Norman (1990, 1999) points out many examples of malfunctioning products due to lack of affordances. Therefore, affordances should be designed and embedded in products (Almquist & Lupton, 2010). The applications of affordances and their effects on usability and experience have been the focus of many design and human computer interaction studies (Heft, 1988a; Hsiao, et al. 2012; Kilbourn & Isaksson, 2007; Maier, et al., 2009; Rourke, 2006; Smets & Overbeeke, 1994; You & Chen, 2007; Gaver, 1991; Oviatt, et al., 2012). However, there was debate against on purposefully designing affordance (Boess & Kanis, 2008).

Figure 6 attempts to illustrate the affordance theory based the human-product interaction. The human-product interaction within Affordance Theory is context dependent, where the context may be the environment, an event, or a time period. A product (stimulus), which carries affordances through its physical qualities, can be considered as a functional entity whose function is what it affords a person to do in a specific context (environment or event). With the product in context, a user acts upon stimulus from the product and uses the product. This model suggests that the meaning of the product is a combination of its utilitarian features and function in a certain environment or usage context.

2.4 Product as a Communication Medium: Product Semantics

Csikszentmihalyi and Eugene (1981) claim that what makes a product special is not only its physical qualities but also what the users do with the product and what the experience means to them. Products that users are strongly attached to are not necessarily the ones that have distinctive aesthetic value, on contrary, it is the ‘trite symbols’ that may make a product meaningful (Csikszentmihalyi, 1991). The product semantics consider these symbolic qualities of products in diverse contextual conditions.

Krippendorff and Butter (1984) define Product Semantics as, “...a study of the symbolic qualities of man-made forms in the cognitive and social contexts of their use and the application of the knowledge gained to objects of industrial design”. Similarly, Buchanan (1993) describes product semantics as a concept of relating symbolic meanings of products in the context of their use. It is the ability of “self-explanation of the product” in which a product demonstrates its function through the interaction between user and the product.
Product Semantics asserts that the product is a communication medium between designer, user and context. It suggests that designers create ‘a message’ that is embedded onto products, which then makes sense for the users. According to Krippendorff and Butter (1984): “An object’s form says: first, something about the object itself; second, something about the larger context of its use; and both to the user who interacts with it and develops the conceptual connection”. They claim that this is an “on-going process of feedback in which product and user finally adjust to each other cognitively and behaviorally”. Although Product Semantic as a theory is well studied and discussed in design studies, there has been limited studies looking at it’s application (Blaich, 1982; Butter, 2012; Demirbilek & Sener, 2003; You & Chen, 2007).

While Product Semantics extends Affordance Theory, there are differences between the two models (You & Chen, 2007). First, Affordance Theory assumes direct perception (bottom-up) whereas Product Semantics values the need for high-level cognitive processing (top-down). According to Affordance Theory, the meaning of an object is what it affords users to do; therefore, the perception is attached to physical qualities of an object (bottom-up cues). In contrast, Product Semantics assumes that the perception relies also on the context such as culture. Second, the major purpose of Affordance Theory is to provide a utilitarian
structure in order to guide the user to behave in a certain way, whereas Product Semantics values symbolic qualities of products.

Finally, affordances can be implemented through the use of ergonomic and anthropometric data in order to provide expected utility. On the other hand, Product Semantics might be implemented through the use of standard conventions for usage, signs, codes and symbols (You & Chen, 2007). Figure 7 provides an illustration of the Product Semantics framework.

In this interpretation of Product Semantics, the designer (sender) is the generator of the product form (stimuli). The user (perceiver) receives and acts upon the product. The conditions on designer’s end, appear to be the concerns the designer has when designing the product, such as business goals and manufacturability; whereas, on the user’s end the conditions focus on budget and socio-economic factors. The intentions, which refer to the meaning (message) embedded into the product form, are sent to the user via the product. The user makes sense of the product when he interacts with it (meaning attribution). Attention appears to be the trigger that attracts the user to the product. The Product Semantics framework suggests on-going feedback between user and designer, with meaning attribution relying on the context of the interaction within the framework.

Figure 7 The model of Product Semantics. Adapted from Krippendorff & Butter (1984) and Krippendorff (1989).
2.5 Product as an Emotional Entity: Product Emotions

Norman's (1990) notion of linking affordances to the usability of products has been favored by many design researchers. Sanders (1992) suggests that products should be ‘useful’ suggesting that a product must be needed; products should be ‘usable’ indicating that a product should be understandable; and finally products should be ‘desirable’ indicating that a user should want it. The notion of desirability, appeal and symbolic meanings in human product interaction lead to product emotion models. Some these models are based on an appraisal process of emotion and Russell's (1980) circumplex model (in which affects are presented in a circular scale in order to measure emotion) (Desmet & Hekkert, 2002; Desmet, 2003; Gorp & Adams, 2012). Models that consider product interaction as being information-processing have been recently introduced (Locher et al., 2010; Overbeeke & Wensveen, 2003). Some advocate that user-product interactions are an aesthetic, meaningful experience (Hekkert, 2006) and others consider this as an experience at visceral, behavioral and reflective levels (Norman, 2004). Some models consider the benefits that users gain from products in three levels, such as hedonic benefits (sensorial and aesthetic), practical benefits (completion of tasks) and emotional benefits (effects on user’s emotions) (Jordan, 2000). Others considered the user-product interaction as behavioral reactions of users towards products as unconscious responses, conscious and unconscious experiences, and conscious relationships (Demir, 2008).

Most of these suggestions about human-product interaction share similar language and common theoretical views. Most can be considered under a top-down approach of perception since these models suggest the involvement of high-level cognitive processes of emotion. Among these approaches, design researchers favor the basic model of product emotions, which is adapted from Appraisal Theory of Emotion.

There are many debates on what emotion is; the Appraisal Theory of Emotion argues that emotions can be elicited by evaluation of situations (Shiota & Kalat, 2012). A person feels happy because he thinks the comment about him was positive, or a person feels angry because the commentary sounded sarcastically positive. The idea of evaluation and interpretation of the situation that evoke emotions is what drives the Appraisal Theory. Therefore, it can be inferred that the theory suggests demand for high-level cognitive effort. According to Ellsworth and Scherer (2003), Appraisal Theory claims that emotions are
patterns of perceptions and interpretations; therefore, they are adaptive. Appraisal Theory assumes (Roseman & Smith, 2001):

- “Emotions are differentiated by appraisals,
- Differences in emotional response can be comprised by differences in appraisals,
- All situations to which the same appraisal pattern is assigned evoke the same emotion,
- Appraisals precede and elicit emotions,
- Appraisal processes evolve to provide effective coping,
- Conflicting, involuntary, or inappropriate appraisal may cause irrational emotions, and
- Change in appraisal can account for induced changes in emotions.”

Frijda (1988) describes emotions as lawful phenomena and uses the analogy of ‘constitution’ to explain sets of rules that establish emotions. First, the ‘law of situational meaning’ suggests that emotions are generated as a response to the meaning structure of the situation; therefore, “Emotions change when meanings change… Input is changed, and output changes accordingly”. He then introduces the ‘law of concern’, which suggests that, “Emotions arise in response to events that are important to the individual’s goals, motives, or concerns”. He claims that emotions are a sign of concerns. Therefore, emotions are generally idiosyncratic (Schifferstein, 2010). A model for ‘product emotions’ generated by Desmet and Hekkert (2002) is built on this idea, and assumes that emotional reaction occurs as an appraisal process in which individual concerns constitute emotional relevance and the meaning attributed to an event is the source of an emotion (Schifferstein, 2010). According to this model, products can be considered as an appealing entity, which a person may like or dislike. The model is defined by four main parameters (concern, appraisal, emotion and stimulus) that explain the cognitive processes associated with product emotions (see Figure 8): Stimulus from the product and user concerns function as inputs in the model. Products are the stimuli that evoke emotional affects in the context, and ‘concerns’ are dispositions that the perceiver recalls and uses as criteria for the emotional process. ‘Appraisals’ are the evaluations and interpretations while ‘emotion’ is the response (Desmet, 2003). Desmet and Hekkert (2007) suggest that the designer should understand the user’s concerns, goals, motives, well-being,
needs, and other sensitivities within the given context in order to understand the emotional responses of users.

2.1 Cognition of Product Experience
Crilly et al. (2004) introduces three major categories of users’ responses to product forms: cognitive, affective and behavioral (see Figure 9). They review works of Baxter (1995), Crozier (1994), Cupchik (1999), Lewalski (1988), Norman (2004), and categorize the cognitive responses to product form into three groups: *aesthetic impression* refers to physical features of the product that create initial reactions, such as attractiveness (appearance), *semantic interpretation* indicating the function and the use of a product (the pleasure and effectiveness of use), and *symbolic association* inferring the overall experience of the product and the message that is attributed, reflection of self-image, personal satisfaction, and memories. According to Crilly et al. (2004), affective responses are based on the three aforementioned categories of cognitive responses. Lastly, behavioral responses refer to actions that users take toward a product.
Many studies indicate that long-lasting feelings toward a product requires a long-term engagement to develop, and the prior interaction, associations and experiences that a user has with a product, and the memories that are evoked, identify what really matters in creating an meaningful experience (Desmet & Hekkert, 2007; Karapanos et al., 2009; Norman, 2004). It can be inferred that the categories introduced might relate to the time spent with the product; however, the distance between a person and the product matters in terms of sensorial experience. Cutting and Vishton (1995) address distance and the cues that a person picks up from the environment, and suggest that while the distance to an object changes the source of the information and cues that a person prefers changes. Similarly, Xenakis and Arnelllos (2013) describe that while approaching a product, user may prefer aesthetic judgment, and then anticipate an interaction when close enough to detect affordances. A user first probably has a distance with the product and checks appearances (aesthetic response), then at the user might require a haptic interaction. After extraction of affordances and semantics occurs, the user gains a full experience of the product and builds responses. The Design Process: Process versus Cognition of Designer.

The models introduced in the previous sections provided a brief overview of human-product interaction and deliver theoretical perspectives on the meaning attribution processes in product experience. However, it is believed that the meaning attribution process begins...
during the product development process. A product begins its life as a result of users intentions, needs, requirements or desires (attention tendencies of users), which trigger the designers’/companies’ interest and become a sets of goals for the rest of the design process. Defining these attention tendencies can be considered as the first manifestation of an idea of a product. In order to actualize an abstract idea into a concrete product, the designer follows certain design phases that involve different levels of interaction initially with users and other stakeholders. These design phases arise due to the certain cognitive processes in which the designer engages. It is essential to review these phases and processes in order to define the meaning attribution process within the product design process.

When the design process is considered as sets of actions or phases to achieve designing, a substantial body of literature can be found. Many agree that the design process begins with a discovery phase, where the nature of the problem is searched and users’ attention tendencies are collected. The interpretation phase includes the process of synthesizing the information collected in the previous phase and listing series items as actionable design criteria. The ideation phase is where designers generate many ideas and try to fulfill the requirements of the problem. The experimentation phase includes evaluation of these initial ideas and building prototypes. The final evolution phase is where users test and evaluate prototypes (see Figure 10). It can be inferred that these approaches are action-driven, or sequence-based since they consider sequences of activities of conventional design process (Groot, 1969; IDEO, 2011; Roozenburg & Eekels, 1995; Rowe & Brown, 2008; Ulrich & Eppinger, 2011; Cross, 2000).

When considering cognitive processes involving the design process of an individual designer, a large body of literature on creativity and design thinking can be found. Creativity in the design process can be considered as a marriage of divergent and convergent thinking. Divergent thinking is defined as the act of generating numerous new ideas that can be used as a background for possible solutions, whereas convergent thinking is considered to be the act of combining information from different sources and finding a single proper solution (Wallach & Kogan, 1965). According to Cross (2000), the design process can be framed as a series of funnel-like shapes that divergent and convergent thinking continuously follow each
other through until the final solution is realized. Lawson (2005) describes the design process as an on-going cognitive process of “…negotiation between problem and solution through three activities of analysis, synthesis and evaluation” (see Figure 11). He suggests that it begins with a brief that has a problem statement that the designer begins to study, learns about the problem, and articulates the requirements. Afterwards, the designer begins to produce alternative solutions, builds and tests them according to the criteria set at the beginning. Finally the communication materials are prepared to present the idea or get it ready for production. Lawson highlights that although the design process is presented as linear, the problem and solution merges together and it becomes a nonlinear, iterative and ongoing activity.

It is important to point out when form giving begins within the design process. Muller (2001) suggests that form giving begins as mental images while a designer begins to analyze the problem. At this level product form is premature, details are absent or even not thought of, and materials are probably not assigned. The product form most likely refers to an idea or initial functions. The conceptualization can begin with associations with existing, related solutions or free associations. This phase involves creative activities, brainstorming and synthesizing. According to Muller (2001), the explanation phase begins when designers manifest this information and knowledge through sketches, drawings, presentations, and any other visualization tools. Ideally, divergent thinking dominates this phase. The synthesis of initial thoughts then becomes preliminary concepts of the solutions. Once ideas are reflected on the paper, details can be added, and materials might be assigned. After the product form reaches a level of certain maturity, the designer might begin to build mock-ups and prototypes in order to have a sense of three-dimensionality/size and begins to test simple
human interactions. Product form is actualized generally through sketches and drawings since they are the representations of abstract ideas and reflections of high-level thinking (Gross, et. al, 1988).

2.2 The Framework

2.2.1 Product Form

The definition of form has been debated in theoretical discussion of both aesthetics and perception. The essence of the discussion is relevant to debates between bottom-up and top-down perception approaches which is whether form is a physical quality (material) or a mental construct (Erlhoff & Marshall, 2007).

When considering form as a physical quality, it is the sets of surfaces that spatially organize and establish a boundary of a matter (Muller, 2001). This boundary defines the contrasts between the surfaces that it covers and the other objects and the environment in which they are surrounded. A form cannot be visually identified without the existence of light and color. An object form has reactions to light such as reflection, refraction etc. which depends on the relationships and structures of the surfaces, and materials from which it is made (Muller, 2001). The components of form consists of point, line, plane (surface), volume (positive or
negative space), value (light and dark), texture and color (Hannah, 2002). A designer uses these components to define a form in space (Porter, 1974). According to Rowena Reed Kostellow, —Hannah (2002) refers to— the complexity of a form occurs when designing interrelationships between these components. Form giving is then a creative activity of merging an idea onto a concrete, physical material. In other words, it is a material embodiment of an idea.

Form, however, is also defined as a mental construct. It is the representation of content and context of the product. Erlhoff and Marshall (2007) defines form as “a very particular class of configurations, namely those that are visualized thought…Form is precisely not the actual concretization—that is, materialization—of a concept or notion, but rather its dematerialized conceptual sibling…It is a mental-visual structure.” It is more than an enclosure, it not only signifies the function —as affordance theory suggest—, but it is also communication medium referring its use in context—as in Product Semantics—, and it evokes emotions —as Product Emotions offers. Form giving, in this case, is not limited to planning the components in order to represent an idea into concrete physical material, yet embodying meaning considering the content and context around the physical material.

Muller (2001) suggests product form can be conceptually analyzed in three levels of categorization based on Feature Theory and Roach and Lloyd's (1978) principles of categorization (see Figure 12). ‘Prototypical categorization’ considers the product schema that deliver similar functionally. The schemas in this category evolve from the same ‘genesis’. ‘Solution-typical categorization’ refers to different variations of product forms that fill the volume prototypical features suggest. This category refers to product forms that are most likely shared across the all products in the same category. ‘Behavior-typical categorization’ refers to specific kind of use or behaviors that users might exhibit when the product form is in certain context or in an environment. According to Muller, the physical qualities play an important role when delivering messages of function and usage, and they are subject to recognition and categorization of the object, where as prototypical and behavior-typical features refer to the meanings of the product form, which are subject to appraisals and memory.
2.2.1 Meaning of Meaning

Osgood et al. (1958), mentions there are as many definitions and concepts of ‘meaning’ as there are disciplines that concern language. According to them, meaning may refer to “relation of signs to situations and behaviors (sociological) pragmatic meaning, and relation of signs to other signs (linguistic) syntactical meaning... relation of signs to their significates (semantical meaning)”’. In most of cases, there is a gap between the pattern of stimulation (which is a sign) and the pattern of significates (meaning). The main question that Osgood et al. (1958) raise is under what conditions do meaning and stimulus highly correlate?

Considering Affordance Theory, ‘meaning’ is a function of the product form. Meaning is the information that product form contains and expresses to its environment and users. Meaning is an intention of conveying and indicating utilitarian features that the product may afford. Meaning suggests an action where action-perceptions are not separable. Meaning is the intuition that a product form elicits about its function and use (Norman, 1990). According
to Krippendorff (1989), “meaning is a cognitively constructed relationship. It selectively connects features of an object and features of its (real environment or imagined) context into a coherent unity’. Krippendorff (1989) introduces four concepts of context that shape meaning of products. The ‘operational context’ refers to user-product interaction and use of products. The ‘socio-linguistic context’ refers to person-person interaction, and suggests social structure and cultural interactions co-construct the meaning of artifacts. The ‘context of genesis’ refers to interactions between designer, producer, distributor, other stakeholders and users influencing the meaning. ‘Ecological context’ indicates artifact-to-artifact, overarching technological and cultural influence on the meaning of products.

Many advocate that meanings of products constitute pleasurable and emotional experiences that occur through the usability of the product (Desmet & Hekkert, 2002; Jordan & Macdonald, 1998; Jordan, 2000; Tractinsky, 1997). Rafaeli and Vilnai-Yavetz (2004) suggests that a product elicits emotions, which then leads to meaning attribution through interpretation whereas Desmet and Hekkert (2007) propose that meaning, aesthetic and emotional experience may not be separated. They are subjective, and rely on preference and concerns (Desmet & Hekkert, 2002). Therefore, there is not always a one-to-one relationship between the appearance of the product (form) and the meaning. Lastly, ‘meaning’ is symbolic association (Csikszentmihalyi & Eugene, 1981). Meaning is the associations that a person makes based on prior experience (Demirbilek & Sener, 2003). It is the results of memory association, knowledge acquirement and social implication through experience.

Schifferstein (2010) suggests that there are multiple layers in product meaning. The physical product is the base layer of the product, which refers to the identity of the object, in which meanings are constructed around primary and secondary functions and affordances. The next layer indicates the package and brand of the physical product. In this case, meaning evolves around producer of the product and producer’s relation to user. The context then introduced as an overarching layer referring the symbolic and cultural value of the product. In this case, the meaning refers to the role of the product in material culture and its impact on environment.

Meaning also appears to be related to personality and it is shared by certain personas. Users prefer certain types of products that reflect their identity — self (Belk, 1988; Malhotra,
1988) and their personality influence their preference and acceptance of products and its’ brand (Bont, Schoormans, & Wessel, 1992; Brody & Cunningham, 1968; Govers & Schoormans, 2005).

In conclusion, ‘meaning’ refers to the utilitarian features and function of the product that a person acts upon. In this case, meaning is not separable from the physical qualities of the product. Meaning may then be defined by use of action verbs in lay language (‘sit’-able so it is chair, ‘push’-able button so I push). Moreover, ‘meaning’ refers to what a user constructs about the product. Meaning of a product may refer to an aesthetic pleasure where physical qualities unify with high usability and memorable experiences. When a person describes these meanings, adjectives may be preferred (sexy car, comfortable chair). Similarly, meaning might refer to the personality of user or the product. In this case, a car would be described as ‘aggressive’ or a phone might be described as ‘friendly’. Furthermore, meaning might indicate the overall experience after a certain period of interaction. In this case, the product is a chair (‘sit’-able) and it makes user feel ‘comfortable’; therefore, it is ‘liked’ or it is ‘pleasurable’. Some might consider this as an emotional product experience. When a user describes a product at this level, a user may prefer adjectives (e.g. the experience using the product is relaxing, it is fun, it is a surprise). Last but not least, ‘meaning’ can be the romantic feeling or nostalgia. In this case, a user may not necessarily use a descriptive term but tell a story or recall a memory. In addition to these concepts, the economic context of the user might be added influence the meaning of the product. Products for which a user invests more money or resources might be more meaningful than those in which less was invested (Kaygan & Sisman, 2008).

2.3 Framework of Meaning Attribution to Product Forms (FMAP)

This section introduces the conceptual framework of the current investigation. The main goal here is to communicate a cohesive, graphical representation of the literature on the topic and provide a holistic view of designer, product and user interaction at the ecological and cognitive level.

It has been suggested that the first interaction of the user with a product occurs at in sensorial level. According to Norman’s (2004) three levels of design model, this phase refers to the visceral level of interaction. Xenakis and Arnellos (2013) suggest that this level of
interaction is an ‘aesthetic experience’ with value propositions. During this interaction, the user may have a certain distance to the product, however, the user already has an idea about what the product is and does. Also, a person probably is attracted by how it looks, sounds, or smells, it other words it already has the user’s ‘attention’. Once a product captures the attention of the user, it will prime the user to collect more sensorial information about the product (selective attention, the product becomes attended stimuli). The bottom-up theories of perception suggest that ‘recognition and categorization’ might occur at this stage, and meaning attribution occurs as a response to the sensorial experience with the product.

Physical qualities of products might contribute to the attention in human-product interaction. A study by Poffenberger and Barrows (1924) suggests that meaning attribution might begin at the physical quality level. Their study offers that the style of lines such as zigzag lines with sharp corners carry different meaning (furiousness, harsh, and agitation) than straight or smooth lines (gentle, laziness and quietness). Muller (2001) claims that when a person captures physical qualities, the attention immediately is drawn to the features of similar forms, objects, and products stored in the memory. If the captured and recalled features are matched or similar, the perceived form is considered in the same category with those recalled from the memory. Therefore, the perceptual qualities of the products cannot be considered separable from the physical qualities. A product form is perceived as soon as it is in the environment either as a source of the perception or the cognitive trigger as accounted for with the top-down approach. Perceptual qualities correspond with how the user thinks and feels about the interaction or what feelings the interaction elicits to them. Unlike physical qualities that can be measured precisely or objectively, perceptual qualities are subjective assessments in which users have their own ways to describe their thoughts, feeling, emotions and experiences. However, the short-term engagement might lead to ‘a love at first sight’ for a product. It maybe a ‘short cut’ that avoids the involvement of high level cognitive processing since the product may not be evaluated through users’ concerns. This may be the result if the product does not have a salient survival importance (product does what user needs so he/she likes it; or it looks gorgeous so the user loves it), or the meaning of the product is already set (product was a gift from an important person, or it already symbolizes an event).
Perceptual qualities of objects can be revealed through understanding the user’s ‘concerns’ within a given context. While the product is apparent to sensorial mechanisms, emotional elicitation occurs through the ‘appraisal process’ driven by user’s concerns. Consequently, the continued experience nurtures the appraisal process positively or negatively. The exposure of positive emotional experience might establish long-term attachments, whereas negative emotional experience might cause avoidance. If the engagement is consciously prolonged then the idea of ‘constant feedback’ can be suggested. The user in this case might need more information about the product to keep evaluating its physical and perceptual features. The constant feedback might be concluded when expectations from the product are not met, or when there is a match between what product offers and user’s concerns. Eventually, once the product has it is meaning or its place in memory, the constant feedback and appraisal process might dissolve.

The involvement of ‘memory’ in appraisal process can be cogitated when considering meaning attribution. Csikszentmihalyi and Eugene (1981) note that the older people are more likely associate products to their memories, whereas younger people tend to associate products with their utilitarian benefits. Desmet (2003) mentions that sometimes products may not directly elicit an emotion, but trigger emotions that are associated with another product in memory. In this case, the meaning is not directly related to product itself but the representation of it in the memory. It is important to point out that the memory is not necessarily veridical and may involve forgetting. Also, memory does not always refer to past experiences. Proactive memory, which is the memory that may interfere with performance in future events, should be considered. Due to the involvement of the memory, a cohort effect between different age groups may be expected for attributing meaning on products.

The meaning of a product appears to have many definitions/origins. It can be drawn from physical qualities of product form, recalled from memory, or associated from another product or person. Meaning might indicate an emotion or refer to personality or brand. The aesthetics and intrinsic qualities of the product evoke meaning. Functionality and utilitarian features of products can generate meaning as well as the interaction that users prefer to act upon. Lastly, context of the situation, event, or user can lead to a certain meaning.
The framework, FMAP, proposes two concepts of context: macro and micro levels. Macro level context includes Krippendorff’s (1989) concepts of socio-linguistic context, context of genesis and ecological context since these concepts refer to overarching meanings around products and they include more than one actor and interactions. The concept of micro level context refers to the concept of context around the designer, product, or user. Krippendorff’s (1989) concepts of ‘operational context’ can be considered at the micro level since it refers to product interaction and the use of products. Muller’s (2001) proposition of ‘categorical context’ can also be considered at the micro level of context since it is defined as the context around the product. Finally, ‘the context of branding and personality’ can be considered at the micro level since it refers to the interaction between brand language, product and users.

The conventional design process suggests that the ‘designer’s intention’ is the starting point of the process. Intentions can be built based upon the designer’s personality, knowledge and experience as well as the context the designer is in. Crilly et al. (2009) organizes intentions around designers’ anticipations of users’ preferences, behaviors and feeling towards product forms. Their study suggests that a designer intends to generate recognizable and engaging product forms. Designers focus on creating elegant, attractive products where product form expresses its function and use. The designer intends to attribute meaning on products, reflect identities of user through product form and eventually elicit emotional responses from the user. Finally, the designer expects that by achieving these intentions the user will respond and act upon the product (Crilly et al., 2009). ‘Conditions’ on the other hand, are set by the context and nature of the design problem. They are driven by the user and signify the user’s concerns (needs, desires etc.). Furthermore, conditions are also determined by the market place and regulations around the product. Business goals, brand values and identity can be considered as conditions that impact the generation of the product form. Finally, materials and production methods, technology and cost are also conditions that designer considers during the manipulation of product form (Crilly et al., 2009).

The proposed framework suggests that the designer should initially discover and understand the concerns and attention tendencies of the user within the given context in the early stages of the design process. When designing for meaning, during the discovery phase, the designer might seek to understand the meaning attribution strategies of the user for the
product or product category. This requires long engagements and constant feedback between designer, product and user. The interpretation, ideation and experimentation phases are pursued following data collection (feedback). During experimentation, design for meaning might require investigation of the perception of meanings for each mock-up and prototype in addition to traditional user feedback and usability scores. The designer ‘analyzes, evaluates and synthesizes’ the collected information and responds by manipulating and reshaping the product forms while considering intentions and conditions. The role of the designer is not only to construct the meaning, but also receive and deliver it, and if needed to re-constructs the meaning during the process (Kazmierczak, 2003).

In conclusion, Figure 13 illustrates the framework of meaning attribution model of product forms (FMAP). According to the proposed framework, sensorial interaction is the first engagement where recognition and categorization occurs. At this level, bottom-up approaches such as the Feature and Affordance Theory might apply. The sensorial information, recognition and categorization might be just enough to create a meaning. In some cases, the constant feedback cycle in appraisal is avoided since the user might attribute meaning to a product without necessarily going through high-level cognitive processes. This would be the case either when the product negatively influences the user, such as hearing an irritating noise, when positive influence occurs, or when the user already has memory that can be associated with the product. In order to assign certain meanings the user does not necessarily need to find the product pleasant or unpleasant; however, eventually the product becomes irritating, hated or loved. An appraisal process may be needed when complex judgments and decision-making are required. The appraisal mechanism processes the information gained from the sensorial mechanism, filters and evaluates it through the attentions and concerns of the users. In some cases, the appraisal mechanism creates new meaning associated with the product itself; however, in some cases appraisals are influenced by memory and an existing meaning can be associated with the product. This process constantly repeats until a meaning attribution occurs or is shaped. If the initial meaning indicates a negative experience then the user might consider avoidance. When the engagement is positive, then the meaning attribution leads to positive emotional experience.
Figure 13 The Framework of Meaning Attribution to Product Forms (FMAP).
MEANING ATTRIBUTION TO PRODUCT FORMS: EXPERIMENTS

Abstract: Each year, companies release new product lines showcasing their advancements in technology and craft through a new form factor. Thus, product forms signify more than an enclosure of the customer’s devices. Product form, whether it is a physical quality (bottom-up approach) or a mental construct (top-down approach), has been debated in theoretical discussions of both aesthetics and perception. Some studies suggest that product form, as a physical quality, informs meanings of functionality and utilitarian features; however, some suggest product form is a communication medium dependent upon the context. Others suggest form is a construct creating meanings by evoking emotion and pleasure. There are limited studies providing a holistic view to these approaches to understand the meaning attribution process of product forms. Extending the aforementioned concept, the current study explores the relationship between how people understand the meaning of an object (e.g. safe, elegant, high-tech look) based on its physical features (roundness in multiple dimensions). A mixed-method approach to understanding the meaning attribution process for product form was investigated in a set of experiments. Participants in experiment one interacted with nine basic geometric objects while participants experienced nine hard drives and nine soap dispenser forms in experiment two. The roundness of object corners were altered from crisp 90 degree edges to blunt round edges along 2- and 3-dimensions. A survey captured rankings of meanings for each object and interviews explored meaning attribution strategies of the participants. Results suggest the involvement of both bottom-up and top-down approaches in participants’ meaning attribution process depending on the meaning of interest. Moreover, the data suggests that a very small changes in roundness of the form lead to large impacts on meaning (suggesting a quadratic relationship between form and meaning). Finally, results indicate the existence of central and highly associated meanings.

Keywords: Meaning Attribution, Emotional Design, Affordances, Product Semantics, Product Interaction, Perception of product meaning.

3.1 Introduction

The expectations from a successful product are no longer limited to its functionality (You & Chen; 2007). Users presume that products should already function as they ought to, and provide high usability (Jordan, 2000). Products fail in the market when they don’t deliver these expectations. However, functionality and usability is no guarantee of success (Kuniavsky, 2003). Products can also be attractive, engaging and suggest meaningful
experiences. Companies and designers have attempted to develop products that are not only functional and beautiful but also are meaningful for the users. The ‘meaning’ here may have many definitions/origins. It may refer to a company’s brand proposition, their technology, or a persona that a company holds; or it may refer to a designer’s intention to deliver messages about the usability of a product and how it functions. On the other hand, users may signify a variety of meanings to products they experience. The intention and the challenge are to match the meanings assigned by the design and those attributed by the user.

The product form, as one of the first layers of interaction, has a vital role when developing meaning. It refers to the organization of sets of surfaces that define the boundary of a ‘matter’ (Muller, 2001). However, product form also refers to a visual thought, a mental construct or mental-visual structure (Erlhoff & Marshall, 2007). Hence, it has been the subject of debates in both theories of perception and aesthetics. Briefly, these debates can be considered as two contradictory yet related approaches. The bottom-up approach values the physical qualities of the objects as the source of the perception (Sternberg, 2008). The main assumption holds that the perception is a pattern recognition process of matching received information with that stored or categorizing objects according to their typicality. Affordance Theory can be positioned under the bottom-up approach (Gibson, 1986, 1977; Krippendorff, 1989; Norman, 1990; You & Chen, 2007). The theory suggests that the invariant fixed qualities of objects such as physical size, form, shape or distance are the affordances that implies “…action possibilities afforded or available to the observer” (Coren et al., 2004). The sensorial experiences, which concerns the first contact between users and products (Coren et al., 2004), have also been examined by many researchers. Studies on this area have focused on sensation, haptic and visual experiences (Gibson, 1962; Heller, 1982; Karana et al., 2009; Klatzky et al., 1993; Lenay, 2010; Schifferstein, 2006; Dagman et al., 2010; Fenko et al., 2011). It can be inferred from these studies that the sensation leads to identification and functions as an information collection process. Users tend to allocate as many senses as necessary to gain intended information from products. However, bottom-up approaches provide limited explanation about the involvement of expectations, knowledge, and prior experience in perception.

The top-down approaches suggest that perception requires high-level cognitive processes, in which sensorial information triggers stored information to construct perception (Sternberg,
These approaches mostly concentrate on emotional elicitation of products (Sanders, 1992; Jordan, 2000; Desmet, 2003; Norman, 2004; Hekkert, 2006) and cognitive aspects of user-product interaction (Khalid & Helander, 2004; Cupchik & Hilscher, 2007; Desmet & Hekkert, 2007; Crilly et al., 2009; Karapanos et al., 2009; Locher et al., 2010; Schifferstein & Hekkert, 2007; Schifferstein, 2010; Pucillo & Cascini, 2014). Studies holding top-down approaches favor the Basic Model of Product Emotions (Desmet & Hekkert, 2002), which is rooted to the Appraisal Theory of Emotions. This theory proposes to guide and find answers to the differentiated nature of emotional response, individual and temporal differences in emotional response, range of situations that evoke emotions, process of emotional response, appropriateness of emotional response to the situations, some of the irrational aspects of emotions, and induced changes in emotions (Roseman and Smith, 2001). Desmet and Hekkert (2002) suggest that emotional reactions occur as an appraisal process in which individual concerns constitute emotional relevance, and in order to design for emotion, the concerns of users should be understood.

There have been comprehensive studies on the significance of semantic features of products and the social context in meaning development (Krippendorff, 2006; Krippendorff & Butter, 1984; Krippendorff, 1989). Krippendorff and Butter (1984) base the study of Product Semantics on affordances, semantics, Shannon’s (1948) basic communication theory, and cognitive processing. According to them “An object’s form says: first, something about the object itself; second, something about the larger context of its use; and both to the user who interacts with it and develops the conceptual connection” (Klaus Krippendorff & Butter, 1984). Therefore, their Product Semantics Framework may be considered partially under both bottom-up and top-down approaches. You and Chen (2007) clarify the difference between Affordance Theory and Product Semantics. According to them, Affordance Theory underscores the utilitarian features of products in order to guide certain behaviors, whereas Product Semantics covers both utilitarian and symbolic qualities. The actualization methods of affordances can be through ergonomics and anthropometric data in order to provide expected utility whereas Product Semantics might actualize through the conventional language of usage, signs and symbols.
Cross (2007) states “designers use ‘codes’ that translate abstract requirements into concrete objects”, and “they use codes to both ‘read’ and ‘write’ in object language”. Products have their own language, which is designed not only through materialization techniques but also ‘codes’ or ‘symbols’. Products become special not only due to the physical qualities of them, but what their users do with it and what the experience means to users (Csikszentmihalyi and Eugene; 1981). Hence, there are many studies in the literature focusing on the topic. Butter (2012) attempts to visualize certain meanings on the design of cab interiors using the Product Semantics approach. Hsiao and Chen (1997) propose semantic and grammatical based approaches to the design process of an office chair. Hsu et al. (2000) suggests semantic differential methods to evaluate product form perception. Egmond et al. (2004) and Fenko et al. (2011) examine the emotions of sound perception in products. Desmet et al. (2008) investigate the relationships between users’ personality and physical product interaction. Govers and Schoormans (2005) look at the relationship between symbolic meaning of product personality and users’ preferences. Karana (2010) discusses that materials carry meaning only when they are in the context that users interact in. Karana et al. (2007) suggest that meaning of products can be based on its form, material, function, color, its context and users’ characteristics. Their study reveals important material qualities providing effective meaning attribution dedicated to certain sensorial channels. For instance, according to the study, ‘softness’ indicates the pressure therefore it is related to tactile sensorial channels. Another study considers the cultural and gender differences in meaning attribution to materials of products (Karana & Hekkert, 2010). The results reveal that shape and function have effects on attributing meanings to materials of products. Gender and culture show minor effects on meaning attribution. Karana et al. (2007) consider the effect of form in attribution of meaning to product materials. The results show that certain forms infer certain materials and meanings. Rounded forms refer to plastics, whereas sharps are considered as metals. Karana et al. (2009) advocate that there may be certain meanings that can be attributed to products via materials, however there are limitations on attributing meaning to materials due to the complex world of materials. Similarly, Georgiev and Nagai (2011) examine the meanings of materials during tactile interaction. Cai et.al. (2003) propose a computer-based semantic evaluation of product aesthetics during the design process. Similarly, Chen and Owen (1997)
investigate computer-based approaches to describe style and form language. Chang and Wu (2007) introduce five types of product forms that are associated with consumer pleasure. Similarly, Hsiao and Chen (1997) explore computer-based applications for product form development that merge rational and emotional qualities. Bloch (1995) proposed a model to investigate customers’ responses to product form. Crilly et al. (2009) present a framework that focuses on the designers’ point of view when shaping product forms. Hsu et al. (2000) inspect the relationship between formal qualities extracted from designers and the subjective evaluation of the user. The study reveals that the perceptions of the users are different than what designers intend. Meaning evaluations are also used when evaluating product impressions and descriptions (Karlsson et al., 2003).

It is expected that every year companies release their new product lines with new form factors. The intention is that the new form factor delivers their brand value and reflects their achievement in technology and crafting. However, the current study assumes that the product form is more than a product enclosure. It signifies functionality, utility, and brand but also evokes emotions, reflects persona, and it becomes a communication medium in social context. While product form is both a physical quality and mental-construct (Erlhoff & Marshall, 2007), any small manipulation in product form might influence the perception of the users and might cause misinterpretations. Despite considerable numbers of studies on affordances, product experience and emotions, the relationship between physical qualities of product form and meaning development is not yet completely understood. The current study investigates the meaning attribution process of product forms and presents two experiments utilizing mixed methods strategies to accommodate both bottom-up and top-down approaches. The current study first explores whether there is a relationship between physical qualities and meanings of product forms. It endeavors to determine how this relationship can be described. Afterwards, it briefly investigates the role of gender, age, occupation when attributing meaning to product forms. It focuses on the meanings of meanings for users and it then explores the strategies that users prefer when attributing meanings. Lastly, it suggests organizing meanings in terms of their relations to bottom-up and top-down approaches. In order to achieve these goals, the study introduces two similar experiments. The first experiment uses abstract objects as stimuli, whereas the second uses two realistic prototype
products. They both utilize the same manipulation techniques. It was hypothesized that when incremental physical manipulation of roundness on the form changes, the perception of meaning also changes incrementally. This then suggests that there is a relationship between roundness and perceived meaning.

3.2 Experiment 1: Abstract Objects

3.2.1 Overview and Methods

Several previous studies indicated that the think-aloud is a challenging method of data collection for both the participants and the researcher (Dagman et al., 2010; Ericsson & Simon, 1993). Similarly, articulating their thoughts in the experiment challenged participants. In order to minimize this challenge, a presentation was prepared based on the findings of previous investigations with the think-aloud method regarding the ways people describe an object verbally. The presentation was given to the participants immediately after they signed the informed consent form. To serve as a reference for the participants, a summary of this presentation was printed and available on the table during the study. The goal was to prime participants prior to the study, encourage them to think-aloud, and use triggers when they ‘felt stuck’. A protocol analysis approach by Ericsson and Simon (1993) followed, encouraging participants to talk by using prompting questions during the study. After reviewing the presentation, the think-aloud method, and having their questions answered, the experiment began with collecting their demographic information in a questionnaire.

Vision self-report and tactile acuity test

This experiment involved physical and visual interaction with objects. Participants were asked to report their vision capabilities and complete a tactile acuity test. Their tactile acuity was measured using JVP Domes (Stoelting Co., Wood Dale, IL). Fourteen domes, each of which has equal groove and ridge width dimensions, were applied to participants’ index finger of dominant hands for about 2-3 seconds, either parallel or orthogonal to the finger axis. Participants were blindfolded and asked to identify the direction of the ridges when
touching the finger (Grant et al., 2006; Remblay et al., 2000; Van Boven & Johnson, 1994). The domes were presented in random order until the participants could not identify the direction correctly. In some cases domes were repeatedly used in order to determine the threshold for the participant.

Preference test (Purchasing a vase)

The study assumes that the meaning attribution process can be affected by participants’ pre-interactions with the objects (their experiences with similar objects in the past) (Hekkert & Leder, 2008). These experiences might play a role in whether or not they “like” an object. A preference test was, therefore, conducted to investigate if participants’ preference of an object influences their rankings of meaning during the second phase of the experiment (It is assumed that this might effect particularly the rankings of elegance). Participants were introduced to a scenario in which they were purchasing flower vases in a shopping mall. They were told that they have enough money to buy three vases and that the purchase is for themselves (not a gift for someone else). Once the scenario and method were described, participants were presented 4”x5” cards with black and white photos of flowers in 24 different vases (see Figure 14). The 24 vases were computer-generated images with varying characteristics; the flowers were the same in each image. Most of the vases had similar typological characteristics to the objects in the latter half of the experiment (n=16); some had unique form features (n=8), some were made of different materials, such as glass or terracotta (n=2), some had patterns on them (n=2) and some of them were darker (n=8) than the others. All cards were coded according to these features and randomly distributed on the table in front of the participants. Hence, the participants were able to review all 24 cards at one time. After picking three cards, the card numbers were recorded.

Study on form and meaning

The third phase of the experiment involved object-meaning rankings. This phase aimed to investigate the relationship between the physical manipulation of the form of an object and individuals’ attribution of meaning. After completing the preference test, participants provided meaning rankings on nine objects. A cube was used as the initial test object since it
is easy to produce and manipulate; the cube is a relatively abstract object that can fit both context and non-context situations.

The simplicity of the cube affords easy modeling of the cube itself and other objects in the computer environment as well as supporting precision prototyping using a CNC router. Eight of the nine objects are variations of the cube. It was assumed that an object sized to fit in the palm of the hand would more likely afford hands-on interaction, and therefore the participant would like to touch them. The dimension of the cube was defined based on the 95th percentile female hand-breadth (8.56cm, or 3.37”). Roundness was the only manipulation applied to the cube when generating variations.

Two types of rounding strategies, two and three-dimensional manipulation, were followed. “Two-dimensional (2d) manipulation” is a condition in which the cube is gradually rounded in increments of 25% only in one direction on the form. This leads to five total objects, which gradually varies from the cube, with no roundness, to a cylinder which is 100% rounded. These objects are named in relation to their magnitude of roundness. The cube is named
object-1, object-2 is 25% rounded, object-3 is 50%, object-4 75%, and finally the cylinder, object-5, is rounded 100%. The “three-dimensional (3d) manipulation” represents the condition in which the cube is rounded in increments of 25% in two directions on the form. Again the manipulation led to five objects, in which the cube has zero roundness and the sphere is 100% rounded. The naming of these objects were again object-1 being the cube, while object-6 was rounded 25%, object-7 50%, object-8 75%, and the sphere, object-9, was 100% rounded. These manipulations were applied to the cube in a 3D modeling application called Rhinoceros; the objects were cut on a CNC machine out of medium density fiberboard (MDF). Their surfaces were smoothed, sanded, and painted a middle-grey tone (see Figure 15). While the manipulations changed the shape of the objects, they did not noticeably change the weight of the objects. These rounding strategies allow a simple manipulation in form to produce multiple objects. Those that have close roundness ratios show similar typological features, while objects at opposite ends of the scale show completely different characteristics (object-1 is a cube, object-5 is a cylinder, and object-9 is a sphere).

Twelve object meanings compiled from literature (Chen et al., 2009; Dagman et al., 2010; Karana, et al., 2007; Zuo et al., 2004) were measured in this phase (e.g. safe, serious, aggressive, cold, warm, soft, hard, playful, fun, masculine, feminine, and elegant). Previous investigations used bipolar likert scales to rate object meanings; for example, participants ranked an object meaning between cold and warm or masculine and feminine in bipolar scale. This format presupposes that cold and warm, or feminine and masculine, are antonyms. Although this notion of bipolarity is frequently noted in the literature, there is evidence that these meanings can be independent (Russell & Carroll, 1999). Moreover, it is important to consider that contradictory meanings can co-exist when evaluating meaning of a product (Hung & Chen, 2009).

One question of interest in this investigation was ‘are these meanings assessed with unipolar scales correlated with each other?’ To test the question of correlation in our study,

2 A pilot investigation was conducted to address the question, ‘Can bipolar questions prime participants to think that these meanings are completely opposite and therefore, influence participants not to look for other connotations of the same meaning?’ In this same pilot investigation, a unipolar approach was also considered, in which the question focused on one specific meaning, such as cold, and the participant ranked the meaning between less or more for the observed object. This approach suggests that cold has an independent meaning from warm. The pilot study was conducted with six participants to test their input using the two types of questions. Three participants received questions with bipolar scales; the remaining three participants answered questions with a unipolar scale. Results showed that some meanings, such as soft and hard can be rated with bipolar scales; however, some meanings, such as feminine and masculine, are not antonyms and should therefore have separate questions with unipolar scales.
twelve independent meanings were rated on a unipolar, 100-point scale (where 0 was identified as less; 100 was more). The data collection forms were prepared as an electronic survey and presented on a tablet. Participants were not able to see their numerical rating; instead, they used a slide bar to move between 0 and 100 when rating each independent meaning. When a participant was ready, a brief introduction to this phase of the study was made. They were told that they would experience nine objects one-by-one, and for each object they would complete a questionnaire. Questions in the questionnaire were the same for all the objects. Objects were randomly introduced right in front of the participant and they were encouraged to interact with them during the study. After finishing ranking for a meaning, they were encouraged to touch the next button on the screen to receive the next question. This procedure was repeated until participant finished all questionnaires for all the nine objects. After finishing this phase they were asked whether they needed a quick break.

Figure 15 Objects used in the experiment.
Note: On the left hand side, the cube. On the top row – 3 dimensional manipulations, the last one at the right hand side is a sphere. On the bottom row – 2 dimensional manipulations, the last one at the right hand side is a cylinder.
Study on form and meaning in context

The last phase of the study was designed to investigate the effect of context. In this phase, nine objects were put on the table together at once, in three rows and three columns, in random order. Participants were asked to picture these objects in five different contexts, and picked three objects that would fit best in each context. The instruction was “If one of these objects would be ‘a flower vase / toy / helmet / high-tech product / high-end product’ which three would be your choice?” Once they picked the three objects, they were also asked to rank them as their first, second and third choice. Every time the context and corresponding question changed, the order of the objects on the table was also changed (again using random placement of the objects in three rows and columns). It was hypothesized that roundness of an object may indicate the product category for a given context.

Overall evaluation of the study

At the end of the study, participants were asked to express their thoughts about the study. This included questions of how easy/hard each task was to complete.

3.2.2 Participants

Participants (N =37, 17 male, 20 female) were recruited from the NC State University Community. Participants were assigned to an age group. Those participants aged 18-30 years old (n=25) were assigned to the younger group while participants aged over 30 years were assigned to the older group (n=12). Participants were also assigned to a group based on their vocation: designer (n=19) or non-designer (n=18). Some of the participants contributed to the study without compensation, whereas some received research credit for their participation (n=12). Ages ranged from 19 to 70 years. Most participants had a only bachelor’s degree (n=24); the rest had graduate degrees (n=12). Most participants wore glasses; none had serious vision impairments.
3.2.3 Results

When looking for outliers and trends in the tactile acuity test data, there were no differences among participant groups (Tactile sensitivity mean=1.25mm, min=0.75mm, max=2.50mm). Preference scores were generated by weighting frequencies of preference for each vase illustration on the cards. Vase illustrations selected as a first choice were weighted higher compared to those selected as a third choice. Results revealed that many participants would prefer to purchase the Card-20 (coded as ‘rounded and sharp corners’ and ‘looks different than others’), Card-14 (coded as ‘sharp corners’ and ‘looks different than others’), followed by Card-18 (coded as ‘sharp corners’ and ‘different material’) and Card-11 (coded as ‘full rounded’ with ‘pattern’). Results suggest that participants selected vase illustrations that show more difference than any other options available. The participants did not favor the objects in the cards that presented similarities (e.g. vases in Card 3-5-9) with objects used during the form and meaning phase of the experiment (see Figure 16). Therefore, mean centering was not appropriate for the data set.

![Figure 16 Preference scores of vases illustrated on the cards](image-url)
**Results from the study on form and meaning**

A series of within-subjects repeated measures analysis of variance tests were conducted for each meaning. The 2d and 3d manipulations are considered separately since they resulted from different topologies in form (from cube to a cylinder and from cube to a sphere). Dependent variables are twelve meanings (safe, serious, aggressive etc.). The between subject factors are age, gender and occupation while roundness served as a within-subject factor. Main effects for age, gender and occupation and their interaction are considered for each meaning. A summary of the results can be found in Table 1 ($F$ values are reported in the text). A post hoc test using Bonferroni correction was used to identify differences in mean scores of meanings across different roundness levels. The partial eta squares ($\eta^2$) represents the portion of explained variance in respective dependent variance.  

A summary of these descriptive statistics can be found in Appendix 1.

<table>
<thead>
<tr>
<th>Round</th>
<th>Gender</th>
<th>Age</th>
<th>Job</th>
<th>GxA</th>
<th>GxJ</th>
<th>AxJ</th>
<th>GxAxJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safe</td>
<td>2d</td>
<td>-</td>
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<tr>
<td>Serious</td>
<td>2d</td>
<td>-</td>
<td>3d</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>Aggressive</td>
<td>2d</td>
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<td>-</td>
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<td>Cold</td>
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<tr>
<td>Warm</td>
<td>2d</td>
<td>-</td>
<td>3d</td>
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<td>Soft</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
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$N=37$, 17 male, 20 female; 18-30 young $n=25$, 31-70 older $n=12$; designer $n=19$, non-designer $n=18$;

2d dimensional manipulation is significant at least $\alpha=.05$ level

3d dimensional manipulation is significant at least $\alpha=.05$ level

Partial eta squares are typically reported as small ($\eta^2=.01$), medium ($\eta^2=.06$), and large ($\eta^2=.14$) effect size (Cohen, 1988).
Results of safeness scores in 2d and 3d manipulation conditions are illustrated in Figure 17. Roundness presented a significant main effect when predicting the safeness of the objects in the 2d manipulation \( F(4, 144) = 10.8, p < .01, \eta^2 = .22 \). There is a significant increase in safeness scores over the increments of roundness in 2d manipulation. This relationship represents a significant quadratic trend; thus a small change in the roundness score leads to a larger impact on safeness \( F(1, 36) = 33.64, p < .01, \eta^2 = .49 \). A post hoc test reveals that safeness is perceived significantly smaller in object-1 (cube with 0\% roundness) then any other objects in the 2d manipulation condition \( M_1 = 30 \). The other objects present similar mean scores of safeness \( M_2 = 59.1, M_3 = 59.8, M_4 = 64.3, M_5 = 60.4 \).

Similar to the 2d manipulation condition, roundness is found to be a significant main effect in the 3d manipulation condition \( F(4, 144) = 14.6, p < .01, \eta^2 = .29 \) with a quadratic trend \( F(1, 36) = 33.64, p < .01, \eta^2 = .48 \). A post hoc analysis indicates that object-1 receives significantly lower safeness scores than objects in 3d manipulation condition \( M_6 = 69.8, M_7 = 72.2, M_8 = 74.2, M_9 = 63.5 \).

**Figure 17** Safeness scores of abstract objects in both 2d and 3d manipulation conditions.

Note: Scores with different letters are statistically significantly different at \( \alpha = 0.05 \) level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.
Serious

A significant main effect of roundness on the seriousness of objects is found in the 2d manipulation condition \([F(4, 144) = 19.05, p< .01, \eta^2 = .34]\). Results reveal that there is a significant decrease in seriousness scores when objects incrementally increase in roundness. The trend in the scores can be explained by a quadratic relationship \([F(1, 36) = 6.03, p< .01, \eta^2 = .14]\). The post hoc test suggests that object-1 receives significantly higher seriousness scores \((M_1=91.0)\) compare to the other objects in the 2d manipulation condition \((M_2= 73.9, M_3= 60.3, M_4= 48.6, M_5= 50.3)\). Roundness is significantly associated with seriousness scores as main effect in 3d manipulation condition \([F(4, 144) = 66.57, p< .01, \eta^2 = .64]\). The relationship shows a significant quadratic effect \([F(1, 36) = 21.38, p< .01, \eta^2 = .37]\); suggesting while roundness incrementally increases seriousness scores rapidly decreases. A post hoc test reveals that object-1, object-6, object-7 and object-9 receive significantly different scores \((M_1= 90.7, M_6= 56.7, M_7= 35.5, M_9= 17.84)\). Objects-7 and 8 are not significantly different \((M_8= 21.6)\); similarly object-8 and object-9, the sphere, are not significantly different either \((M_9= 17.84)\) (see Figure 18). As highlighted in Table 1, older participants associate roundness and seriousness differently than younger participants \([F(4, 144) = 3.45, p< .05, \eta^2 = .10]\). Similarly, there are significant differences between male and female participants who have different occupations (designers vs. non-designers) \([F(4, 116) = 2.83, p< .05, \eta^2 = .08]\). Furthermore, results suggest the relationship between roundness and seriousness in the 3d manipulation condition depends upon gender, age, and occupation \([F(4, 116) = 3.96, p< .05, \eta^2 = .12]\).

Aggressive

Roundness is found to be a main effect for aggressiveness of objects in the 2d manipulation condition \([F(4, 144) = 18.79, p< .01, \eta^2 = .34]\). The relationship between aggressiveness scores and the roundness can be described in a quadratic trend \([F(1, 36) = 27.84, p< .01, \eta^2 = .43]\). This suggests that while roundness increases objects are perceived to be less aggressive. A post hoc test reveals that aggressiveness is perceived significantly higher in object-1 (cube) then all other objects \((M_1=67)\). Other objects present similar mean scores for aggressiveness.
Figure 18: Seriousness scores of abstract objects in both 2D and 3D manipulation conditions.
Note: Scores with different letters are statistically significantly different at \( \alpha = 0.05 \) level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.

\[ M_2 = 38.5, M_3 = 30, M_4 = 26, M_5 = 24.7 \]. Older participants associate roundness and aggressiveness differently than younger participants \([F(4, 116) = 2.65, p < .05, \eta^2 = .08]\).

Roundness is also found to be a significant main effect in the 3D manipulation condition \([F(4, 144) = 37.96, p < .05, \eta^2 = .51]\). A quadratic trend explains relationship between roundness and aggressiveness \([F(1, 36) = 34.29, p < .01, \eta^2 = .48]\). Similar to the 2D manipulation, while roundness increases, aggressiveness scores of objects manipulated in 3D are rapidly decreased. A post hoc test suggests that object-1 is found to have a significantly higher aggressiveness score \((M_1 = 67.05)\) when compared to other objects in the 2D manipulation condition. Objects-6 and 7 are significantly different \((M_6 = 30.2, M_7 = 16.11)\) while objects-7 and 8 are similar. The other objects do not show difference between aggressiveness scores \((M_8 = 13.5, M_9 = 14.27)\). Results of aggressiveness scores in the 2D and 3D manipulation conditions are illustrated in Figure 19.
Figure 19 Aggressiveness scores of abstract objects in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at $\alpha=0.05$ level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.

**Cold**

Results indicate that roundness is significantly associated with coldness scores in the 2d manipulation condition $[F(4, 144) = 8.6, p< .01, \eta^2=.19]$ where the relationship between roundness and coldness of objects can be described in a quadratic relationship $[F(1, 34) = 5.91, p< .05, \eta^2=.14]$. A post hoc test reveals that object-2, 3, 4 and 5 are not significantly different than each other ($M_1=71.1, M_2= 54$). There are no differences in coldness scores between object-1, and 2 ($M_3= 45.7, M_4= 42.5, M_5= 39.3$).

The relationship between coldness and roundness is also significant in the 3d manipulation condition $[F(4, 144) = 15.68, p< .01, \eta^2=.30]$ with a quadratic trend $[F(1, 36) = 34.2, p< .01, \eta^2=.25]$. A post hoc test suggests that object-1 is perceived with significantly greater coldness ($M_{cube}=71.1$) than the other objects. The scores of the other objects are similar to coldness ($M_6= 42.3, M_7= 36.7, M_8= 28.5, M_9= 27.8$). Results are presented in Figure 20.
Figure 20 Coldness scores of abstract objects in both 2d and 3d manipulation conditions.
Note: Scores with different letters are statistically significantly different at $\alpha=0.05$ level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X and Y series are associated with the 3D.

**Warm**

Roundness is found to be a significant main effect for warmness scores in the 2d manipulation condition \([F(4, 144) = 5.75, p< .01, \eta^2= .13]\). The relationship between warmness and roundness shows linear trend \([F(1, 36) = 16.76, p< .01, \eta^2 = .31]\), suggesting while roundness increases the perception of warmness increases respectively. A post hoc test reveals that object-1, object-2 and 3 are not significantly different in their warmness scores ($M_1=19.6$, $M_2= 30$, $M_3= 37.1$, $M_4= 43.9$, $M_5= 31.8$). Also, object-2, 3, 4 and 5 are not significantly different than each other. When only age group differences are considered, the relationship between warm and roundness differs in the 2d manipulation condition \([F(4, 140) = 2.79, p< .05, \eta^2 = .07]\). Results reveal that there is also a significant relationship between roundness and warmness in 3d manipulation condition \([F(4, 144) = 11.13, p< .01, \eta^2 = .23]\).
Figure 21 Warmness scores of abstract objects in both 2D and 3D manipulation conditions. Note: Scores with different letters are statistically significantly different at α=0.05 level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.

The relationship fits a quadratic trend \([F(1, 36) = 23.72, p< .01, \eta^2 = .39]\) indicating that unlike 2D manipulation condition, while roundness increases, warmness scores increase rapidly. A post hoc test shows that object-1 \((M_1=19.6)\) is found to be significantly lower than all other objects in the 3D manipulation condition. The warmness scores of the other objects are found to be similar to each other \((M_2= 39.7, M_3= 54.9, M_4= 56.1, M_9= 50.8)\). Summary of the results is illustrated in Figure 21.

**Soft**

There is a significant relationship between softness scores and roundness in the 2D manipulation condition \([F(4, 144) = 16.53, p< .01, \eta^2 = .31]\); a quadratic relationship is observed \([F(1, 36) = 10.18, p< .01, \eta^2 = .22]\). Softness scores rapidly increase when roundness increases. A post hoc test indicates that Object-1 \((M_1=8.19)\) receives a significantly lower softness score compared to other objects. Objects-2, 3, and 4 do not show significant
differences ($M_2=28.08$, $M_3=41.1$, $M_4=50$). Object 4 is perceived as highly soft when compared to other objects; however, objects 3, 4 and 5 are not significantly different ($M_4=50$, $M_5=42.5$).

Roundness is also found to significant for softness in the 3d manipulation condition [$F(4, 144) = 50.43$, $p<.01$, $\eta^2=.58$] with a quadratic trend [$F(1, 36) = 48.48$, $p<.01$, $\eta^2=.57$]. Except for objects 8 and 9 ($M_8=75.62$, $M_9=68.41$), all objects are found to be significantly different ($M_6=43.4$, $M_7=63$). Softness scores in the 2d and 3d manipulation conditions are illustrated in Figure 22.

![Softness of Abstract Objects](image)

Figure 22 Softness scores of abstract objects in both 2d and 3d manipulation conditions.
Note: Scores with different letters are statistically significantly different at $\alpha=0.05$ level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.
A significant relationship between hardness and roundness of objects in the 2d manipulation condition is found \( F(4, 144) = 12.3, p< .01, \eta^2 = .25 \), and the trend of the data is quadratic \( F(1, 36) = 6.45, p< .05, \eta^2 = .15 \). When roundness increases, perception of hardness decreases rapidly. Object-1’s hardness score is significantly higher than other objects (\( M_1 = 91.4 \)). Objects-2 and 3 present moderate hardness scores (\( M_2 = 76.5, M_3 = 66.4 \)). Object-4 is ranked with lowest hardness score, however there are not significant differences in hardness scores between objects-3, 4 and 5 (\( M_4 = 60.7, M_5 = 61.9 \)). Roundness is also found to be a main effect in the 3d manipulation condition \( F(4, 144) = 34.97, p< .01, \eta^2 = .49 \). The relationship between hardness and roundness can also be described with a quadratic trend \( F(1, 36) = 13.13, p< .01, \eta^2 = .26 \). A post hoc test reveals that Objects-1 and 6 are significantly different (\( M_1 = 91.4, M_6 = 62.2 \)) from Objects-7, 8, and 9; again object-1 receives the highest hardness score. There are no significant differences in hardness between object-7, 8 and 9 (\( M_7 = 44.8, M_8 = 31.5, M_9 = 33.5 \)). Results are presented in Figure 23.

Figure 23 Hardness scores of abstract objects in both 2d and 3d manipulation conditions.

Note: Scores with different letters are statistically significantly different at \( \alpha = 0.05 \) level between different levels of roundness. Means with same letter are not significantly different. Letters A &B series are associated with the 2D manipulation; X & Y series are associated with the 3D.
A relationship between playfulness and roundness is found in 2d manipulation conditions \([F(4, 144) = 10.02, p< .01, \eta^2= .21]\) and the relationship shows significant quadratic trend \([F(1, 36) = 11.08, p< .01, \eta^2= .23]\). Results suggest that playfulness scores increase rapidly in increments of roundness. A post hoc test suggests that object-1, 2, 3, and 4 receive significantly similar scores where object-2 is rated lowest \((M_1 = 32.5, M_2= 25.3, M_3= 26.2, M_4= 36.7)\). Object-5 is ranked with significantly higher playfulness score \((M_5 = 62.2)\) than the other objects in the 2d manipulation condition. Roundness and playfulness are also significantly related in the 3d manipulation condition \([F(4, 144) = 21.99, p< .01, \eta^2= .37]\). However, in this case the trend is significantly linear \([F(1, 36) = 72.27, p< .01, \eta^2= .67]\) suggesting that an increase in the playfulness score occur similarly regardless of which increment of increase is occurring for roundness. The playful scores of objects-1 and 6 \((M_1 = 32.5, M_6= 51.6)\) object-6, 7 and 8 are not found significantly different from each other \((M_7 =55.6, M_8 = 67.5)\). Object-9 is significantly different and higher than any other objects in 3d manipulation condition \((M_9 = 90.1)\). Results are illustrated in Figure 24.

Fun

Fun and roundness is found to be significantly related in 2d manipulation condition \([F(4, 144) = 6.68, p< .01, \eta^2= .15]\). The relation between these terms is quadratic \([F(1, 36) = 4.71, p< .05, \eta^2= .11]\) in which fun scores rapidly increase with the increments of roundness. A post hoc test reveals that objects-1, 2, 3, and 4 do not show any significant differences while object-2 is ranked with the lowest fun score \((M_1 = 29.4, M_2= 21.4, M_3= 35, M_4= 36)\). Objects-3, 4 and 5 are not significantly different from each other; object-5 receives the highest fun score \((M_5 = 53.5)\). A relationship between fun and roundness is also found in 3d manipulation condition \([F(4, 144) = 25.27, p< .01, \eta^2= .41]\). The relationship can be described as linear \([F(1, 36) = 76.23, p< .01, \eta^2= .68]\). A post hoc test suggest that objects-1 and 6 \((M_1 = 29.4, M_6= 42.7)\); objects-6 and 7 \((M_7 = 55.3)\); objects-7 and 8 \((M_8 = 66.8)\) are not significantly different from each other whereas object-9 is ranked significantly different and higher all others \((M_9 = 87)\). Results are illustrated in Figure 25.
Figure 24 Playfulness scores of abstract objects in both 2d and 3d manipulation conditions.
Note: Scores with different letters are statistically significantly different at $\alpha=0.05$ level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.

Figure 25 Fun scores of abstract objects in both 2d and 3d manipulation conditions.
Note: Scores with different letters are statistically significantly different at $\alpha=0.05$ level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.
**Masculine**

Roundness is a main effect for masculinity scores in the 2d manipulation condition \([F(4, 144) = 38.74, p < .01, \eta^2 = .51]\). This relationship is quadratic; the masculinity scores rapidly decrease while roundness increases \([F(1, 36) = 7.39, p < .01, \eta^2 = .17]\). Except for objects-4 and 5 (\(M_4 = 36.3, M_5 = 38.2\)) and for objects-3 (\(M_3 = 54.2\)) and object-5, masculinity scores of all objects show significant difference (\(M_1 = 85.2, M_2 = 67.2\)). However, when only gender group (male vs female participants) differences are considered, the relationship between masculinity and roundness differs in 2d manipulation condition \([F(4, 140) = 2.63, p < .05, \eta^2 = .07]\). Participants associate increased roundness with decreased masculinity in object with 3d manipulation \([F(4, 144) = 36.74, p < .01, \eta^2 = .50]\). A quadratic trend represents the relationship between these two terms \([F(1, 36) = 26.39, p < .01, \eta^2 = .42]\). Results suggest that objects-1, 6, 7 and 8 are rated with significantly different masculinity scores (\(M_1 = 85.2, M_6 = 54.6, M_7 = 38.2, M_8 = 22.6\)). Objects-8 and object-9 (\(M_9 = 31.1\)) do not show significant difference; while, object-8 receives the lowest masculinity score. Results are illustrated in Figure 26.

![Masculinity Scores of Abstract Objects](image)

**Figure 26** Masculinity scores of abstract objects in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at \(\alpha =0.05\) level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.
Feminine

Femininity and roundness of objects in 2d manipulation significantly are related \( F(4, 144) = 12.18, p< .01, \eta^2= .25 \). The relationship presents a linear trend \( F(1, 36) = 30.4, p< .01, \eta^2= .46 \), which suggests that the changes in femininity scores occurs equally regardless of the level of roundness. A post hoc test reveals that objects-1 and 2 are not significantly different from each other where object-1 is found to be the least feminine of all \( (M_1= 12.3, M_2= 19) \). Objects-3, 4 and 5 are not significantly different from each but are significantly different from objects- 1 and 2 \( (M_3= 31.3, M_4= 40, M_5= 39) \). Roundness is also found significant for femininity scores in the 3d manipulation \( F(4, 144) = 20.01, p< .01, \eta^2= .35 \). The relationship is quadratic \( F(1, 36) = 9.17, p< .01, \eta^2= .20 \). Object-1 is found significantly different and low, compare to the other objects \( (M_1= 12.3) \). Objects-6 and 7 are not significantly different and are moderately feminine \( (M_6= 35.4, M_7= 47.5) \). Objects-7, 8 and 9 are also not significantly different where object-9 is ranked highest for femininity \( (M_9= 55, M_9= 59.1) \). Results are presented in Figure 27.

![Femininity Scores of Abstract Objects](image)

Figure 27 Femininity scores of abstract objects in both 2d and 3d manipulation conditions.
Note: Scores with different letters are statistically significantly different at \( \alpha=0.05 \) level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.
Elegant

The roundness of objects in the 2d manipulation is not found to be associated with elegance \[ F(4, 144) = 1.91, p=.11, \eta^2=.05 \]. Mean scores of elegance for each are not significantly different from each other \((M_1=54.5, M_2=49, M_3=48.1, M_4=40.5, M_5=37.7)\). Similarly, roundness is not found related to elegance in the 3d manipulation condition \[ F(4, 144) = 1.32, p=.26, \eta^2=.03 \] and mean scores are not significantly difference from each other \((M_1=54.5, M_6=43.5, M_7=44, M_8=39.7, M_9=38.2)\). However, elegance scores present significant differences between occupation groups (designer vs. non-designers) \[ F(4, 116) = 2.89, p<.05, \eta^2=.09 \]. Furthermore, there is significant interaction between gender and occupation \[ F(4, 116) = 2.93, p<.05, \eta^2=.09 \] suggesting scores provided by female and male participants as well as designers and designers are significantly different. Results of elegance scores in the 2d and 3d manipulation conditions are illustrated in Figure 28.

![Elegance Scores of Abstract Objects](image)

**Elegance Scores of Abstract Objects**
(Note: Roundness and elegance are not found associated)

Figure 28 Elegance scores of abstract objects in both 2d and 3d manipulation conditions.
Note: Elegance and roundness are not found significantly related. Scores with different letters are statistically significantly different at \( \alpha=0.05 \) level between different levels of roundness. Means with same letter are not significantly different. Letters A &B series are associated with the 2D manipulation; X & Y series are associated with the 3D.
Results from study on form and meaning in context

Frequencies of preference for each object in both the 2d and 3d manipulation conditions are used to generate in-context scores. Objects, which are preferred as first choice, are weighted higher compared to those preferred as a third choice. Scores are plotted separately for each contextual situation (vase, toy-like, helmet, high-tech, high-end). Results are presented in Figure 29.

Figure 29 In-context scores for objects in both 2d and 3d manipulation condition.
Results suggest that objects are not more likely to be seen as vase depending on their level of roundness in both the 2d and 3d manipulation. However, toy-likeness appears to be associated with the roundness of the objects. Objects in the two extreme ends (cube, cylinder and sphere) are found to be more toy-like than those with middle or moderate roundness in both the 2d and 3d manipulation conditions. The 2d and 3d manipulation conditions presented opposite trends in Helmet context. It appears that when objects are rounded in 2d, they are perceived less helmet-like whereas an increase in roundness in 3d is perceived to be more helmet-like. Object-2 with 25% roundness is found to be more high-tech than other objects in the 2d manipulation condition. Results suggest that high-techness decreases rapidly when the roundness increases in both the 2d and 3d manipulations. High-endness presents the same trend in both 2d and 3d manipulation conditions. When the roundness increases, the perception of high-endness decreases rapidly.

**Correlations between meanings**

Meaning scores for each participant of each object was used to explore overall correlations. The data was first converted into a stacked format, which resulted in n=185 cases representing each of the 2d and 3d manipulation conditions, then a Pearson correlation coefficient was computed to assess the relationships between meanings. Correlations that are significant and between .20 to .29 represent a weak relationship; .30 to .39 is considered moderate; .40 to .69 is strong and .70 and higher is very strong (correlation between to meanings) (Field, 2013). Correlation results are summarized in Table 2 and Table 3. Overall in the 2d manipulation condition, there is a strong, positive correlation between safeness and softness. An increase in safeness is associated with increase in softness. Seriousness is found to have a strong, positive correlated with aggressiveness, harness and masculinity. Aggressiveness of objects presents strong, positive correlation with coldness, hardness, and masculinity whereas aggressiveness and softness show a strong, negative correlation. There is a strong, negative correlation between coldness and both warmness and softness. Warmness presents strong, positive correlation with softness and femininity, and a negative correlation with hardness. Softness and femininity a present positive correlation whereas softness and both hardness and masculinity present strong, negative correlations. There is strong, positive
correlation between hardness and masculinity and a negative correlation between hardness and femininity. Finally, a very strong, positive correlation is found between fun and playfulness. Results for the 3d manipulation condition, overall, safeness appears to have a strong, negative correlation with aggressiveness and hardness. Seriousness is found to have a strong, positive correlation with aggressiveness, coldness, hardness and masculinity; seriousness also has a strong, negative correlation with softness, playfulness, fun and femininity. There is a strong, positive correlation between aggressiveness and coldness, hardness, and masculinity whereas there was a strong, negative strong correlation between aggressiveness and softness, playfulness, and fun. Coldness is found to have a strong, positive correlation with hardness and negative correlation with warmth, softness, playfulness, and fun. Warmness presents a strong, positive correlation with softness, fun and femininity and a negative correlation with hardness. Softness shows strong, positive correlations with playfulness, fun, femininity and negative correlations with hardness and masculinity.

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</table>

**Correlation is significant at the 0.01 level (2-tailed).**  
*Correlation is significant at the 0.05 level (2-tailed).**  
**Bold values indicate strong and very strong correlations.**
Table 3 Correlation between meanings in 3D manipulation for Abstract Objects

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** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Bold values indicate strong and very strong correlations

There is a strong, positive correlation between hardness and masculinity and negative correlations with playfulness, fun, and femininity. Fun presents a very strong, positive correlation with playfulness and a strong, positive correlation with femininity. Finally, femininity is found to have a strong, negative correlation with masculinity.

**Pathfinder Network**

Pathfinder is a scaling method of analysis that translates a proximity matrix into a network structure by determining the optimal paths between nodes and representing the data visually (Schvaneveldt et. al, 1988). Pathfinder network structures use nodes to represent terms (meanings in this case) and utilize relatedness scores of these terms to identify how closely they are linked (Goldsmith, et. al, 1991). Pathfinder structures do not represent the data in a hierarchical organization unless this type of organization exists in the data set (Goldsmith, et. al, 1991) (the details on how pathfinder algorithm works can be found in Schvaneveldt et. al, 1988; Gillan, Breedin, & Cooke, 1992; and Goldsmith et al., 1991). It is believed that visual representation of relationships between meaning scores provides better understanding.
order to pursue this analysis, meaning scores for each participant of each object is converted into a stacked format so that a proximity matrix can be generated by SPSS (2013). In order to generate the simplest pathfinder network, $r = \infty$, and allowable path length of $p = n-1$ (n refers to number of terms, in this case there are 12 meaning terms, therefore $p = 11$) is preferred (Schvaneveldt et al., 1985) in KNOT Pathfinder software (Interlink, 1990). The 2d and 3d manipulation proximity data was entered together. There are 12 nodes for each meaning with a total of 14 links among them. Most of these links are shared between 2d and 3d manipulation conditions (58%). These two networks were found significantly similar ($p < .01$). The numbers next to the links indicate the weight of the links between two connected meanings. Lower numbers indicate less psychological distance and greater link weights between meanings. Pathfinder networks contain four fundamental elements: cycles referring to the sequence of terms whose links begin and end with the same concept; sub-networks referring to the groups of connected cycles; strings or chains; and central nodes (Gillan et al., 1992; Schvaneveldt et al., 1985). Sub-networks may represent high-level a associative structure; while chains may refer to dimensional structures in the data; and central node (nodes that have at least three connections with others meanings and shared in both 2d and 3d conditions) links may indicates relationships between terms that are not recursive (Gillan et al., 1992). Overall, the structure between seriousness, aggressiveness, hardness and masculinity can be considered as a sub-network with high weight; therefore, they are highly associated with each other. These meanings appear to be proximal to each other. Seriousness, elegance and femininity establish a chain among each other. Softness appears to be a central node between safeness, warmness and fun, which suggests that these meanings are individually associated with softness. Playfulness and fun are very close to each other and they establish a chain. Femininity and masculinity appears to be distant to each other; however, they are not as far distant comparing cold-warmness and hard-softness. Results of Pathfinder analysis can be found in Figure 30.

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4 The similarity, which is the number of common links shared in both networks divided by total number of unique links in two networks, between two networks is calculated by the correspondence of links in the two networks (Gillan et al., 1992).
**Final Evaluation of Experimental Study One**

Participants were asked to reflect on their opinion of how easy or hard the tasks were in the study at the end. Participants found the preference test to be a relatively easy task to accomplish (78.4% rated the tasks as easy, 10.8% as neutral, and 10.8% hard). They also indicated that experiencing these objects were relatively easy tasks as well (59.5% rated the tasks as easy, 8.1% as neutral, and 32.4% hard). However, evaluating objects meaning using a questionnaire received ratings of high difficulty (11% rate this as difficult, 89% as very difficult). The ranking objects in context rated as an easy task (62.2% rated this as easy, 10.8% as neutral, 27% hard). Finally, participants found rating the difficulty of the study overall as a relatively easy task (59.5% rated this as easy, 21.6% as neutral, 18.9% hard).

Figure 30 Pathfinder network of meanings in 2d and 3d manipulation conditions for abstract objects. Note: Numbers next to links indicate the weight of the links between two connected meanings. Lower numbers indicate less psychological distance and greater link weights between meanings. Central node is presented in bold.
3.3 Discussion

The results are able to present correlations between object forms and meanings. There is a common pattern across all meanings and manipulations. Objects in extremes (object-1 cube, object-5 cylinder, and object-9 sphere) are commonly considered different than objects in the middle range since each of these three has unique topological qualities. Objects in the middle increment of roundness (50%) mostly received average meaning scores. This suggests that these form factors might lead to misinterpretations of meanings due to their roundness level. However, objects close to extremes are more likely to receive extreme meaning scores, which may infer that participants have a clear idea about the meaning form association.

Overall, when objects become more rounded, scores for safeness increase whereas the sharper the object, the more serious it is perceived. Even slight roundness on the object form leads to significantly less aggressiveness compared to a cube. Coldness is considered the opposite of warmness. The rounder the object is, the warmer (and less cold) it is perceived. Although participants might think these two meanings are temperature related, they might unconsciously consider other connotations such as ‘inviting’ since the temperature of the objects were same. Similarly, softness and hardness are perceived as highly opposite of each other. However, objects that are slightly rounded are considered both hardness and softness. The rounder the objects are the softer they are perceived even though the physical quality of softness and hardness are the same for all the objects. Participants might allocate a different strategy or consider different connotations when ranking coldness and hardness. Playfulness and fun showed similar yet slightly different patterns. Participants might consider that fun could mean something slightly different than playfulness. An object can be fun but this does not necessarily mean it is also playful. Objects in the 3d manipulation condition received greater playfulness and fun rankings than the two-dimensional condition objects. The rounder the object is, the more playful and fun it becomes. Results suggest that both masculinity and femininity might co-exist in one product form. This may be a result of the data collecting method (unipolar scale). The more rounded the object, the more feminine and less masculine it is perceived. However, object-5, the cylinder, and object-9, the sphere, are considered less masculine than the previous objects. These two objects are considered more feminine than the previous ones. This suggests that these two meanings shouldn’t be
considered complete opposites when considering object forms. Elegance does not show any significance difference in rating associated with roundness manipulation. All objects are received similar elegance ratings. The meaning attribution process for elegance may therefore require more information than just roundness.

Seriousness, aggressiveness, and warmthness presents significant differences among age groups and masculinity considered differently by each gender group. However, except for elegance, occupation (designer and non-designer) do not show a difference in meaning and manipulations.

Softness appears to be a central node with strong, positive correlations with playfulness, fun, femininity and negative correlations to hardness and masculinity. Similarly, seriousness and aggressiveness can be considered as central nodes. Focusing on these meanings for designing for meaning is promising. Some of the meanings that are used in this study showed strong correlations. This indicates that some of them are perceived completely differently (Cold-warm) from each other whereas some may be highly associated and co-exist (masculine feminine).

Further analysis is needed since the objects used experiment-1 are abstract and have different topological qualities; the results may change when objects are more concrete. Also, strategies that participants prefer when they attribute meaning on the objects are still not clear. Experiment-2 accommodates these two aspects (use of concrete objects and exploration of strategies in meaning attribution).

3.4 Experiment 2: Concrete Products

3.4.1 Overview and Methods

The second experiment aimed to investigate whether the results gained from experiment one (using abstract objects) differs when the stimuli are concrete products. Therefore, experiment two followed a very similar procedure to experiment one. Realistic prototypes of external drives and soap dispensers (as representative of concrete products with simple forms) were preferred as stimuli. It was assumed that these concrete product examples provide more contextual information.
The mean scores of three hard drives and soap dispensers commonly found in the market were used to determine the dimensions of the parent prototypes. The same physical manipulation technique that used in experiment one was utilized to generate eight children product forms for each set of products resulting in 9 external hard drives and 9 soap dispensers (see Figure 31). All prototypes were modeled in CAD software and cut on a CNC machine out of polyurethane foam. The average weights of each sample hard drives and soap dispensers are used when weighting each prototype (each child prototype weighted same as the parent prototype). Their finished surfaces were smooth and painted a middle-grey tone. Regular USB cables were attached to the hard drive prototypes, and market available pump tops were screwed on the soap dispensers in order to improve reality. It is essential to mention that due to the dimension limitations of the hard drives, manipulations (roundness in different directions) were very subtle — especially in 3D manipulation condition. However, manipulations were more obvious in soap dispensers due to their dimensions. Also, prototypes with 0% roundness are named as hard drive-1 or soap dispenser-1; hard drive-2 or soap dispenser-2 have 25% roundness; hard drive-3 or soap dispenser-3 have 50% roundness; hard drive-4 or soap dispenser-4 have 75% roundness; and hard drive-5 or soap dispenser-5 have 100% roundness in the 2d manipulation condition. Similarly in the 3d manipulation, prototypes with 25% roundness are named hard drive-6 or soap dispenser-6; hard drive-7 or soap dispenser-7 with 50% roundness; hard drive-8 or soap dispenser-8 with 75% roundness; and hard drive-9 or soap dispenser-9 with 100% roundness.

Different group of participants were used in the second experiment. Participants were provided with a brief overview of the experiment. Once they were agreed to participate, they were exposed to a verbal presentation in order to trigger them to think about the topic of form and meaning attribution. The think-aloud approach and the protocol analysis technique were also used during the second experiment. Participants completed a questionnaire, which included demographic and vision information, and a big five personality test (John & Srivastava, 1999). Afterwards, they completed the JVP domes tactile acuity test. The card preference test was not used in this experiment due to time limitation and the results from experiment one.
Figure 31 Prototypes used in experiment: top-left corner is the parent hard drive prototype with 0% roundness. The first row is 2D manipulation condition (left to right from 25% to 100% roundness). The second row is 3D manipulation condition of hard drives. Bottom-left corner is the parent soap dispenser prototype with 0% roundness. The third row is 2D manipulation condition for soap dispensers and the last row is the 3D manipulation conditions with 25% roundness to 100%.

The presentation order of the product category, whether the hard drive or soap dispenser was first, and the order of the products within the product category were randomly introduced to participants one-by-one. They were asked to provide rankings of meanings for each product; participants were encouraged to touch and experience each product. Data collection procedures, meanings (safe, serious, aggressive, cold, warm, soft, hard, playful, fun, masculine, feminine, and elegant) and the question types utilized in this experiment were the same as described for experiment one.

Once participants finished ranking all the products of the same product type, the strategies, which they preferred to use when attributing meanings, were captured through
semi-structured interview. This phase of the experiment was video recorded. Participants were asked: “What is the idea/strategy you used when you think/ranked ‘safeness’ of these products?” or “What makes you think these objects were ‘safe’ or not? After this phase of the study, participants were allowed to have five-minute break.

The test on the contexts of the product was considered at the micro level. Hard drives were ranked in terms of their “High-tech look” whereas soap dispensers were rated for their “High-end (elite) look” on a slide bar from 0 (indicating less) to 100 (referring more). Participants were not able to see the exact value of their input on the scale while proving ratings. Although the presentation of the product category was randomized, the order of presentation of each product within the category was not random.

Participants were then asked to order the products (hard drives and soap dispenser) arranging them in order of their purchase preference. Prototypes were presented once for each manipulation condition (e.g 5 hard drives that were only 2D manipulated). This process was repeated until participants provided their preference rankings for all prototypes.

Finally, participants were asked to evaluate the experiment. This phase included five questions in which participants were asked how easy or hard each task was to complete and the difficulty of the overall experiment using a 7-point likert scale.

3.4.2 Participants

Participants (N=73: 37 male, 36 female) were recruited from the NC State University Community and were assigned to a group based upon age. Those participants aged 18-30 years old (n=44) were assigned to the younger group while participants aged over 30 years were assigned to the older group (n=29). Participants were also assigned to a group based on their vocation: designer (n=31) or non-designer (n=42). Some of the participants contributed to the study without compensation, whereas some received research credit for their participation. Participants’ ages ranged from 19 to 70 years with an average of 32 years. Most participants had a bachelor degree (n=50) and many had graduate degrees (n=22); one participant had only a high school education.
3.4.3 Results

A series of within-subjects repeated measures analysis of variance was conducted for each meaning and condition. Prototype category, hard disk (hd) and soap dispenser (sd), is considered separately. Similar to experiment-1, the dependent variables are twelve meanings and between subject factors are age, gender and occupation. Roundness served as a within-subject factor. Results are summarized in Table 4 and Table 5. A summary of statistics can be found in Appendix 2 (for hard drive prototypes) and Appendix 3 (for soap dispenser prototypes).

Table 4. Repeated Measures ANOVA results with Interactions – Hard drive Prototypes

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N=73, 37 male, 36 female; 18-30 young n=44, 31-70 older n=29; designer n=31, non-designer n=42;
□=2D dimensional manipulation is significant at least α=.05 level
■=3D dimensional manipulation is significant at least α=.05 level
Table 5. Repeated Measures ANOVA results with Interactions – Soap Dispenser Prototypes

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</tbody>
</table>

N = 73, 37 male, 36 female; 18-30 young n=44, 31-70 older n=29; designer n=31, non-designer n=42;■ = 2D dimensional manipulation is significant at least α = .05 level, ○ = 3D dimensional manipulation is significant at least α = .05 level

Safe

Safeness and roundness is found significantly associated in 2d manipulation condition for hard drives \[F(4, 288) = 7.63, p < .01, \eta^2 = .09\] and the relationship presents a significant quadratic trend \[F(1, 72) = 15.27, p < .01, \eta^2 = .18\]. A post hoc test reveals that safeness is perceived significantly low in hard drive-1 (hd-1 with 0% roundness) then any other objects in 2d manipulation condition \(M_{HD1} = 45\). Hard driven-1, and 3 are found significantly different whereas hard drives-2, 4 and 5 present similar mean scores of safeness \(M_{HD2} = 55.2, M_{HD3} = 64.2, M_{HD4} = 61.5, M_{HD5} = 62.1\). Roundness is also significant main effect in 3d manipulation condition \[F(4, 288) = 16.88, p < .01, \eta^2 = .19\] with linear trend \[F(1, 72) = 43.44, p < .01, \eta^2 = .38\]. However, as highlighted in Table 4, there is an interactive effect between gender and age \[F(4, 260) = 3.04, p < .05, \eta^2 = .04\] and age and occupation \[F(4, 260) = 3.64, p < .01, \eta^2 = .05\]. hd-1 and 7; hd-6, 7 and 8; and hd-8 and 9 do not significantly differ in safeness \(M_{HD1} = 45, M_{HD6} = 57.6, M_{HD7} = 57.1, M_{HD8} = 65.8, M_{HD9} = 74\).
Roundness is also a main effect in the 2d manipulation for soap dispensers \(F(4, 288) = 7.63, p< .01, \eta^2 = .09\). The relationship between roundness and safeness presents a quadratic trend \(F(1, 72) = 43.44, p< .01, \eta^2 = .37\). A post hoc test reveals that safeness scores of soap dispenser-1 (sd-1 with 0% roundness) and 5 and sd-2, 3, 4, and sd-5 do not significantly different from each other (\(M_{SD1} = 37, M_{SD2} = 51.6, M_{SD3} = 54.7, M_{SD4} = 55.1 M_{SD5} = 50\)).

There is a significant relationship between roundness and safeness in the 3d manipulation condition for soap dispensers \(F(4, 288) = 13.03, p< .01, \eta^2 = .15\) with a quadratic trend \(F(1, 72) = 8.74, p< .01, \eta^2 = .15\). Safeness of soap dispenser-1 is found to be significantly different compared to other soap dispensers with the lowest score (\(M_{SD1} = 37\)). Sd-6, 7, 8 and sd-7, 9 do not show significant difference in safeness while sd-9 received the highest safeness score (\(M_{SD6} = 54.1, M_{SD7} = 64.2, M_{SD8} = 55.8 M_{SD9} = 68.5\)). Results of safeness scores in the 2d and 3d manipulation conditions for hard drives and soap dispensers are illustrated in Figure 32.

![Safeness scores](image)

Figure 32 Safeness scores of hard drive and soap dispenser prototypes in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at \(\alpha=0.05\) level between different levels of roundness. Means with same letter are not significantly different. Letters A&B series are associated with the 2D manipulation; X & Y series are associated with the 3D.
There is significant association between seriousness and roundness in the 2d manipulation condition for hard drives \( F(4, 288) = 105.5, p < .01, \eta^2 = .59 \), and the relationship shows a quadratic trend \( F(1, 72) = 20, p < .01, \eta^2 = .21 \). A post hoc test suggests that seriousness scores for all hard drives, except for hd-3 and 4, are significantly different where hd-1 is rated highest and hd-5 lowest for seriousness scores \( (M_{HD1} = 83.8, M_{HD2} = 61.4, M_{HD3} = 40.6, M_{HD4} = 35.6, M_{HD5} = 24.4) \). Occupation (designer vs. non-designer) appears to be a main effect \( F(4, 260) = 3.36, p < .01, \eta^2 = .05 \). There is also difference in seriousness ratings between gender and age \( F(4, 260) = 3.21, p < .05, \eta^2 = .04 \) and there is interaction between gender and occupation groups \( F(4, 260) = 2.54, p < .05, \eta^2 = .03 \). Furthermore, a three-way interaction between gender, age and occupation is found \( F(4, 260) = 3.97, p < .01, \eta^2 = .05 \). In the 3d manipulation condition, roundness \( F(4, 288) = 23.47, p < .01, \eta^2 = .26 \) and age \( F(4, 260) = 3.64, p < .01, \eta^2 = .05 \) are found as main effects for hard drives. The relationship between roundness and seriousness can be represented as quadratic \( F(1, 72) = 6.38, p < .01, \eta^2 = .81 \). There is a significant difference in seriousness ratings for hd-1, hd-6 and hd-9 \( (M_{HD1} = 83.8, M_{HD6} = 64.8, M_{HD9} = 49.1) \). Hard drive-6, 7 and 8 do not show significant difference in seriousness scores \( (M_{HD7} = 60.7, M_{HD8} = 60.4) \).

Roundness is found to be a significant main effect in the 2d manipulation condition for soap dispensers \( F(4, 288) = 64.33, p < .01, \eta^2 = .47 \). A linear relationship can be observed between roundness and seriousness ratings \( F(1, 72) = 205.7, p < .01, \eta^2 = .74 \). Soap dispenser-1 and 2 \( (M_{SD1} = 78.5, M_{SD2} = 69.4) \); sd-3 and 4 \( (M_{SD3} = 50.5, M_{SD4} = 42.0) \) do not show significant difference in seriousness scores. Soap dispenser-1 is found to be rated highly for seriousness whereas sd-5 is found to have the lowest rating \( (M_{SD5} = 30.6) \). However, as highlighted in Table 5 there is an interaction effect between gender and age \( F(4, 260) = 3.54, p < .01, \eta^2 = .05 \). Roundness is also found to be a main effect in the 3d manipulation condition for soap dispensers \( F(4, 288) = 93.13, p < .01, \eta^2 = .56 \) with cubic trend \( F(1, 72) = 8.83, p < .01, \eta^2 = .10 \). A post hoc test suggests that except for sd-8 and 9 all other soap dispensers have significantly different seriousness ratings \( (M_{SD1} = 78.5, M_{SD6} = 64.6, M_{SD7} = 50.1, M_{SD8} = 28.2, M_{SD9} = 25.9) \). Results are summarized in Figure 33.
Figure 33 Seriousness scores of hard drive and soap dispenser prototypes in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at $\alpha=0.05$ level between different levels of roundness. Means with same letter are not significantly different. Letters A &B series are associated with the 2D manipulation; X & Y series are associated with the 3D.

Aggressive

Aggressiveness and roundness are found to be associated in the 2d manipulation condition for hard drives [$F(4, 288) = 65.1, p< .01, \eta^2= .47$]. The relationship is quadratic [$F(1, 72) = 39.6, p< .01, \eta^2= .35$]. Hard drive-1, 2 and 3 are found to be significantly different in ratings of aggressiveness where hd-1 received the highest ($M_{HD1}= 68.5, M_{HD2}= 40.7, M_{HD3}= 28.7$). Hard drive- 3, 4 and 5 do not show significant differences ($M_{HD4}= 26.3 \ M_{HD5}= 20.2$). Roundness is a main effect in the 3d manipulation condition for hard drives [$F(4, 288) = 45.5, p< .01, \eta^2= .38$] with quadratic relationship [$F(1, 72) = 18.15, p< .01, \eta^2= .20$]. Aggressiveness ratings for hard drive-1 is found to be significantly different compare to the other hard drives ($M_{SD1}= 68.5$). Hard drive-6 and 7 ($M_{HD6}= 46.2, M_{HD7}= 36.8$); hd-7 and 8 ($M_{HD8}= 34.6$); hd-8 and 9 ($M_{HD9}= 26.4$) do not show significant differences in aggressiveness ratings.
Participants associated roundness and aggressiveness in 2d manipulation condition for soap dispensers \[F(4, 288) = 75.12, p< .01, \eta^2= .51\]. The relationship presents a quadratic relationship \[F(1, 72) = 17.67, p< .01, \eta^2= .19\]. A post hoc test reveals that soap dispensers 1, 2, 3, and 4 presents significantly different aggressiveness scores whereas sd-4 and 5 do not \((M_{SD1}= 75, M_{SD2}= 58, M_{SD3}= 40.4, M_{SD4}= 31.7, M_{SD5}= 25.8)\). The relationship between roundness and aggressiveness is also found as a main effect in 3d manipulation condition for soap dispensers \[F(4, 288) = 107.7, p< .01, \eta^2= .60\] with a quadratic relationship \[F(1, 72) = 20.74, p< .01, \eta^2= .22\]. All soap dispensers present significantly different aggressiveness ratings where sd-1 received the highest and sd-9 received the lowest \((M_{SD1} = 75, M_{SD6}= 49.2, M_{SD7}= 33.2, M_{SD8}= 19.4, M_{SD9}= 11.9)\). Also, gender appears to be a main effect for aggressiveness \[F(4, 260) = 3.66, p< .01, \eta^2= .05\] and there is an interaction effect between gender and age groups \[F(4, 260) = 3.41, p< .01, \eta^2= .05\]. Results are illustrated in Figure 34.

**Figure 34** Aggressiveness scores of hard drive and soap dispenser prototypes in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at \(\alpha=0.05\) level between different levels of roundness. Means with same letter are not significantly different. Letters A &B series are associated with the 2D manipulation; X & Y series are associated with the 3D.
Cold

Roundness and coldness are found to be significantly associated in the 2d manipulation condition for hard drives \([F(4, 288) = 58.29, p< .01, \eta^2 = .44]\) with a quadratic relationship \([F(1, 72) = 25.19, p< .01, \eta^2 = .25]\). Hard drives-1, 2, 3 and 5 have significantly different coldness scores whereas hd-3 and 4 are not significantly different \((M_{HD1} = 71.1, M_{HD2} = 47.8, M_{HD3} = 32.2, M_{HD4} = 29.1, M_{HD5} = 21.4)\). Roundness is also a main effect in the 3d manipulation condition \([F(4, 288) = 53.15, p< .01, \eta^2 = .42]\) with a quadratic relationship \([F(1, 72) = 13.97, p< .01, \eta^2 = .16]\). Warmness scores of hard drives-1, 2 and 3 are found to be significantly different whereas scores of hd-3 and 4, hd-4 and 5 are not to be found different \((M_{HD1} = 13.6, M_{HD2} = 29, M_{HD3} = 45.5, M_{HD4} = 43.7, M_{HD5} = 53.6)\). Also, there is an interaction effect between gender and age groups \([F(4, 260) = 2.73, p< .05, \eta^2 = .04]\).

Warm

There is a significant association between roundness and warmness in the 2d manipulation condition for hard drives \([F(4, 288) = 53.15, p< .01, \eta^2 = .42]\) with a quadratic relationship \([F(1, 72) = 13.97, p< .01, \eta^2 = .16]\). Warmness scores of hard drives-1, 2 and 3 are found to be significantly different whereas scores of hd-3 and 4, hd-4 and 5 are not to be found different \((M_{HD1} = 13.6, M_{HD2} = 29, M_{HD3} = 45.5, M_{HD4} = 43.7, M_{HD5} = 53.6)\). Also, there is an interaction effect between gender and age groups \([F(4, 260) = 2.73, p< .05, \eta^2 = .04]\).
Figure 35 Coldness scores of hard drive and soap dispenser prototypes in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at $\alpha=0.05$ level between different levels of roundness. Means with same letter are not significantly different. Letters A &B series are associated with the 2D manipulation; X & Y series are associated with the 3D.

Roundness is also found to be a main effect in the 3d manipulation for hard drives $[F(4, 288) = 39.18, p< .01, \eta^2= .35]$ with a quadratic relationship $[F(1, 72) = 83.99, p< .01, \eta^2= .53]$. Hard drives-1, 6, 8 and 9 received significantly different warmth scores, and ratings of hard drive-6 and 7; hd-7 and 8 are not found to be significantly different ($M_{HD1} = 13.6, M_{HD6} = 27, M_{HD7} = 30, M_{HD8} = 36.8, M_{HD9} = 47$). Also, there are interaction effects between gender and occupation $[F(4, 260) = 6.54, p< .01, \eta^2= .09]$, and gender and age groups $[F(4, 260) = 3.81, p< .01, \eta^2= .05]$.

Warmness of soap dispensers in the 2d manipulation condition is also found to be associated with roundness $[F(4, 288) = 32.62, p< .01, \eta^2= .31]$. The relationship between warmth and roundness has a linear relationship $[F(1, 72) = 68.26, p< .01, \eta^2= .48]$. Soap dispensers-1, 3 and 4 receive significantly different warmth scores where scores for soap dispensers-1 and 2 and sd-4 and 5 were not significantly different ($M_{SD1} = 15.6, M_{SD2} = 21.6, M_{SD3} = 29.7, M_{SD4} = 39.3, M_{SD5} = 45.8$).
Warmness scores of hard drive and soap dispenser prototypes in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at $\alpha=0.05$ level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.

Roundness appears to be a main effect in the 3d manipulation condition [$F(4, 288) = 58.25, p< .01, \eta^2= .44$] with a linear relationship [$F(1, 72) = 131.5, p< .01, \eta^2= .64$]. Also, occupation is found to be a main effect [$F(4, 260) = 3.94, p< .01, \eta^2= .05$]. All soap dispensers except sd-8 and 9 are found to be significantly different in terms of their warmness scores ($M_{SD1}= 15.6, M_{SD6}= 26.2, M_{SD7}= 37.6, M_{SD8}= 53.1, M_{SD9}= 58.8$). Results are summarized in Figure 36.

Soft

Results of softness are illustrated in Figure 37. Softness and roundness are found to be associated in the 2d manipulation condition for hard drives [$F(4, 288) = 90.77, p< .01, \eta^2= .55$] with a quadratic relationship [$F(1, 72) = 16.79, p< .01, \eta^2= .19$]. Hard drives-1, 2, 3 and 5 have significantly different softness scores whereas hd-3 and 4 are not significantly different
Figure 37 Softness scores of hard drive and soap dispenser prototypes in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at α = 0.05 level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.

(M_{HD1} = 8.4, M_{HD2} = 26.7, M_{HD3} = 48.4, M_{HD4} = 49.4, M_{HD5} = 63.1). Moreover, gender is found to be a main effect [F(4, 260) = 4.23, p < .01, \eta^2 = .06]. Roundness is also a main effect in the 3d manipulation condition for hard drives [F(4, 288) = 58.73, p < .01, \eta^2 = .44]. The relationship between warmness and roundness in the 3d manipulation condition is linear [F(1, 72) = 136.3, p < .01, \eta^2 = .65]. Overall, scores of softness between hard drives-1, 6, 8, and 9 are found to be significantly different whereas scores of hd-6 and 7 are not (M_{HD1} = 8.4, M_{HD6} = 25.8, M_{HD7} = 32.1, M_{HD8} = 42.2, M_{HD9} = 55.1). Also gender is found to be a main effect [F(4, 260) = 2.63, p < .05, \eta^2 = .04]. Furthermore, there is an interaction between gender and age [F(4, 260) = 4.11, p < .01, \eta^2 = .06] and between age and occupation groups [F(4, 260) = 2.89, p < .05, \eta^2 = .04].

The main effect of roundness over softness of soap dispensers in the 2d manipulation condition is found [F(4, 288) = 56.96, p < .01, \eta^2 = .44] to be linear [F(1, 72) = 158.8, p < .01,
η^2 = .68]. All soap dispensers except sd-4 and 5 receive significantly different softness scores (\(M_{SD1} = 9, M_{SD2} = 19.7, M_{SD3} = 29.3, M_{SD4} = 41, M_{SD5} = 47.1\)). Also, the softness scores between gender and age groups are found to be different \(F(4, 260) = 3.25, p < .05, \eta^2 = .04\). Roundness is a main effect over softness in the 3d manipulation condition \(F(4, 288) = 128.3, p < .01, \eta^2 = .64\) with a linear relationship \(F(1, 72) = 331.4, p < .01, \eta^2 = .04\). A post hoc test suggests that softness scores of all soap dispensers show significant differences (\(M_{SD1} = 9, M_{SD2} = 25.4, M_{SD3} = 46.6, M_{SD4} = 62.5, M_{SD5} = 74\)). Also, there are significant differences (interactions) in softness score between occupation groups in the 3d manipulation condition \(F(4, 284) = 133.3, p < .05, \eta^2 = .03\).

**Hard**

Roundness is found to be a significant main effect in the 2d manipulation condition for hard drives \(F(4, 288) = 91.47, p < .01, \eta^2 = .56\) with a quadratic relationship \(F(1, 72) = 33.3, p < .01, \eta^2 = .31\). Hard drives-1, 2, 3, and 5 are found to be significantly different in terms of their hardness scores. Hard drive-3 and 4 and hd-4 and 5 do not show significant differences between each other (\(M_{HD1} = 85.7, M_{HD2} = 58.3, M_{HD3} = 39.1, M_{HD4} = 35.5, M_{HD5} = 26.6\)). Also, there is a significant difference (interaction) in hardness scores between gender groups \(F(4, 284) = 2.61, p < .05, \eta^2 = .03\). Roundness is also found to be a main effect in the 3d manipulation condition for hard drives \(F(4, 288) = 50.88, p < .01, \eta^2 = .41\). The relationship between hardness and roundness can be described as quadratic \(F(1, 72) = 6.6, p < .01, \eta^2 = .08\). Hard drives-1, 6, 8 and 9 present significantly different hardness scores whereas hd-6 and 7 and hd-7 and 8 do not (\(M_{HD1} = 85.7, M_{HD6} = 62.3, M_{HD7} = 55.4, M_{HD8} = 47.4, M_{HD9} = 36.1\)). Additionally, there are interaction effects between gender and age \(F(4, 260) = 4.31, p < .01, \eta^2 = .06\) and between age and occupation groups \(F(4, 260) = 2.69, p < .05, \eta^2 = .04\) in the 3d manipulation condition for hard drives.

Hardness and roundness are found to be associated in the 2d manipulation condition for soap dispensers \(F(4, 288) = 91.47, p < .01, \eta^2 = .56\). The relationship between these two terms quadratic \(F(1, 72) = 4.23, p < .05, \eta^2 = .05\). Soap dispensers-1, 2, 3, and 4 present significant differences in hardness scores whereas sd-4 and 5 do not (\(M_{SD1} = 82.5, M_{SD2} = 69.6, M_{SD3} = 56.5, M_{SD4} = 43, M_{SD5} = 40\)). Roundness is also a main effect in the 3d
manipulation condition for soap dispensers \(F(4, 288) = 101.7, p< .01, \eta^2= .58\). The relationship between roundness and hardness is quadratic \(F(1, 72) = 5.22, p< .05, \eta^2= .07\). Hardness scores for soap dispensers-1, 6, 7, and 8 are significantly different from each other. Soap dispenser-8 and 9 are not significantly different \((M_{SD1} = 82.5, M_{SD6} = 62, M_{SD7} = 47.4, M_{SD8} = 25.8, M_{SD9} = 18.6)\). Results of hardness scores in the 2d and 3d manipulation conditions for hard drives and soap dispensers are illustrated in Figure 38.

![Figure 38](image)

**Figure 38** Hardness scores of hard drive and soap dispenser prototypes in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at \(\alpha=0.05\) level between different levels of roundness. Means with same letter are not significantly different. Letters A &B series are associated with the 2D manipulation; X & Y series are associated with the 3D.
Playful

There is a main effect of roundness over playful scores in the 2d manipulation condition for hard drives $[F(4, 288) = 73.78, p< .01, \eta^2= .50]$. The relationship between roundness and playfulness is quadratic $[F(1, 72) = 4.28, p< .05, \eta^2= .05]$. Hard drives-1, 2, 3, and 4 have significantly different playfulness scores ($M_{HD1}= 11.4, M_{HD2}= 25.5, M_{HD3}= 43$). Hard drives-4 and 5 do not have significantly different playfulness scores ($M_{HD4}= 52.3, M_{HD5}= 61$). Roundness also appears to be a main effect in the 3d manipulation condition for hard drives $[F(4, 288) = 45.23, p< .01, \eta^2= .38]$ with a linear relationship $[F(1, 72) = 7119.4 p< .01, \eta^2= .62]$. A post hoc test reveals that hard drives-1, 6, 8 and 9 present significantly different playfulness scores whereas hard drives-6 and 7 and hd-7 and 8 do not ($M_{HD1}= 11.4, M_{HD6}= 22.4, M_{HD7}= 29.6, M_{HD8}= 35.2, M_{HD9}= 47$). Additionally, there are interaction effects between gender and age $[F(4, 260) = 6.38, p< .01, \eta^2= .08]$ and age and occupation $[F(4, 260) = 3.49, p< .01, \eta^2= .05]$. The relationship between roundness and playfulness depends on gender and age and age and occupation.

The playfulness of soap dispensers in the 2d manipulation condition is associated with the roundness of the drives $[F(4, 288) = 50.78, p< .01, \eta^2= .41]$. In this case, a quadratic trend can be used to represent the relationship between playfulness and roundness $[F(1, 72) = 5.95, p< .05, \eta^2= .08]$. Soap dispensers-1, 3, 4, and 5 demonstrate significantly different playfulness scores. Playfulness scores of soap dispensers-1 and 2 are not significantly different ($M_{SD1}= 15.4, M_{SD2}= 20.4, M_{SD3}= 30.2 M_{SD4}= 44.1, M_{SD5}= 57.3$). Also, there is a difference between occupation groups in terms of playfulness of soap dispensers in the 2d manipulation condition. Roundness is a main effect in the 3d manipulation condition for soap dispensers $[F(4, 288) = 67.55, p< .01, \eta^2= .48]$. The relationship between roundness and playfulness is quadratic $[F(1, 72) = 4.32, p< .05, \eta^2= .05]$. Soap dispensers-1, 7 and 8 received significantly different playfulness scores whereas sd-1 and 6 and sd-8 and 9 do not differ significantly ($M_{SD1}= 15.4, M_{SD6}= 22.2, M_{SD7}= 30.9, M_{SD8}= 52.8, M_{SD9}= 61$). Results are summarized in Figure 39.
Figure 39 Playfulness scores of hard drive and soap dispenser prototypes in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at α = 0.05 level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.

**Fun**

There is a significant relationship between fun and roundness in 2d manipulation condition for hard drives. \( F(4, 288) = 62.04, p < .01, \eta^2 = .46 \). The relationship is quadratic \( F(1, 72) = 5.29, p < .05, \eta^2 = .06 \). Fun scores are found to be significantly different between hard drives-1, 2, 3 and 4. Hardrives-4 and 5 receive similar scores \( M_{HD1} = 12.3, M_{HD2} = 30.6, M_{HD3} = 43.8, M_{HD4} = 51.4, M_{HD5} = 61 \). Also, there is difference in fun scores between occupation groups \( F(4, 260) = 2.60, p < .05, \eta^2 = .03 \). Roundness is also found to be a main effect in the 3d manipulation condition for hard drives \( F(4, 288) = 35.21, p < .01, \eta^2 = .32 \) with a quadratic relationship \( F(1, 72) = 94.34, p < .01, \eta^2 = .56 \). Hard drives-1, 6, 8 and 9 show significant difference in their fun scores whereas hd-6 and 7 and hd-7 and 8 do not \( M_{HD1} = 12.3, M_{HD6} = 24.6, M_{HD7} = 30.1, M_{HD8} = 34.2, M_{HD9} = 44.9 \).
Roundness is also found to be a significant main effect in the 2d manipulation condition for soap dispensers \( [F(4, 288) = 66.44, p< .01, \eta^2 = .48] \) with a quadratic relationship \( [F(1, 72) = 13.7, p< .01, \eta^2 = .16] \). A post hoc test indicates that soap dispensers-1, 3, 4, and 5 present significant differences whereas sd-1 and 2 do not differ significantly \( (M_{SD1} = 17, M_{SD2} = 22.4, M_{SD3} = 31.6, M_{SD4} = 43.5, M_{SD5} = 61) \). The relationship between roundness and fun is also found in the 3d manipulation condition \( [F(4, 288) = 53.3, p< .01, \eta^2 = .42] \) with a linear relationship \( [F(1, 72) = 130.5, p< .01, \eta^2 = .64] \). Soap dispensers-1, 7, 8 and 9 present significantly different fun scores whereas soap dispensers-1 and 2 are found to be similar \( (M_{SD1} = 17, M_{SD6} = 24.2, M_{SD7} = 34.3, M_{SD8} = 48.8, M_{SD9} = 58.6) \). Results are illustrated in Figure 40.

Figure 40 Fun scores of hard drive and soap dispenser prototypes in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at \( \alpha=0.05 \) level between different levels of roundness. Means with same letter are not significantly different. Letters A &B series are associated with the 2D manipulation; X & Y series are associated with the 3D.
Masculine

A significant main effect between roundness and masculinity is found in the 2d manipulation condition for hard drives \( F(4, 288) = 108.6, p < .01, \eta^2 = .60 \). The relationship between these terms is quadratic \( F(1, 72) = 5.29, p < .05, \eta^2 = .06 \). Overall, hard drives-1, 2, 3 and 5 show significantly different masculinity scores and hard drives-3 and 4 present similar scores \( (M_{HD1} = 77.8, M_{HD2} = 61.1, M_{HD3} = 37, M_{HD4} = 31.5, M_{HD5} = 21.1) \). However, there are significant differences in masculinity scores between occupation groups \( F(4, 260) = 3.0, p < .05, \eta^2 = .04 \). Also, an interaction between gender and age groups is found \( F(4, 260) = 2.8, p < .05, \eta^2 = .04 \). Furthermore, a three-way interaction between age, gender and job exists \( F(4, 260) = 5.58, p < .01, \eta^2 = .07 \). This suggests that the relationship between roundness and masculinity depends on age, gender and occupation. Roundness appears as a main effect in the 3d manipulation condition for hard drives \( F(4, 288) = 30.76, p < .01, \eta^2 = .30 \) with a linear relationship \( F(1, 72) = 120.1, p < .01, \eta^2 = .62 \). Hard drives-1, 6, 9 are found to be significantly different in their masculinity scores. Masculinity scores of hard drives-2 and 3, hd-3 and 4, and hd-4 and 5 do not present significant difference between each other \( (M_{HD1} = 77.8, M_{HD6} = 63.3, M_{HD7} = 60.4, M_{HD8} = 53.6, M_{HD9} = 45.8) \).

There is a relationship between roundness and masculinity in the 2d manipulation condition for soap dispensers \( F(4, 288) = 74.97, p < .01, \eta^2 = .51 \) which can be explained by a quadratic relationship \( F(1, 72) = 4.51, p < .05, \eta^2 = .05 \). A post hoc test reveals that soap dispensers-1, 2, 3, and 5 receive significantly different masculinity scores whereas soap dispenser-3 and 4 do not \( (M_{SD1} = 81.1, M_{SD2} = 69.2, M_{SD3} = 49, M_{SD4} = 40.6, M_{SD5} = 31) \). Roundness and masculinity is related in the 3d manipulation condition for soap dispensers \( F(4, 288) = 90.17, p < .01, \eta^2 = .55 \). The relationship between these two terms is quadratic \( F(1, 72) = 6.11, p < .01, \eta^2 = .07 \). A post hoc test reveals that overall soap dispensers-1, 6, 7 and 8 present significantly different masculinity scores. Soap dispensers-8 and 9 have similar masculinity scores \( (M_{SD1} = 81.1, M_{SD6} = 66.8, M_{SD7} = 49, M_{SD8} = 31.8, M_{SD9} = 26.7) \). However, the relationship between roundness and masculinity depends on gender and age \( F(4, 260) = 6.85, p < .01, \eta^2 = .09 \). Results are presented in Figure 41.
Figure 41 Masculinity scores of hard drive and soap dispenser prototypes in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at $\alpha=0.05$ level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.

**Feminine**

Results of femininity are summarized in Figure 42. Femininity of hard drives in the 2d manipulation condition is related to roundness [$F(4, 288) = 80.99$, $p<.01$, $\eta^2=.52$]. A quadratic trend can be used to represent the relationship between these two terms [$F(1, 72) = 7.21$, $p<.01$, $\eta^2=.09$]. Overall, a post hoc test suggests that hard drives-1,2, 3 and 4 receive significantly different femininity scores and hard drives-4 and 5 are found to be similar ($M_{HD1} = 14.8$, $M_{HD2} = 29.3$, $M_{HD3} = 46.7$, $M_{HD4} = 57$, $M_{HD5} = 63.8$). Also, gender is found to be a main effect between roundness and femininity [$F(4, 260) = 3.18$, $p<.01$, $\eta^2=.04$]. Furthermore, femininity scores are significantly different depending on gender and age groups [$F(4, 260) = 3.73$, $p<.01$, $\eta^2=.05$]. Roundness is found to be a significant main effect in the 3d manipulation condition for hard drives [$F(4, 288) = 42.19$, $p<.01$, $\eta^2=.37$] with a
Figure 42 Femininity scores of hard drive and soap dispenser prototypes in both 2d and 3d manipulation conditions. Note: Scores with different letters are statistically significantly different at $\alpha=0.05$ level between different levels of roundness. Means with same letter are not significantly different. Letters A &B series are associated with the 2D manipulation; X & Y series are associated with the 3D.

linear relationship $[F(1, 72) = 127.0, p< .01, \eta^2=.63]$. Overall, hard drives-1, 6, 8 and 9 receive significantly different femininity scores whereas hard drives-6 and 7 do not ($M_{HD1}=14.8, M_{HD6}= 27.8, M_{HD7}= 30.8, M_{HD8}= 38.5, M_{HD9}= 51.5$). However, the relationship between roundness and femininity depends on gender and age groups $[F(4, 260) = 3.44, p< .01, \eta^2=.05]$.

Roundness is also a main effect in the 2d manipulation condition for soap dispensers $[F(4, 288) = 53.5, p< .01, \eta^2=.42]$ with a linear relationship $[F(1, 72) = 106.5, p< .01, \eta^2=.59]$. A post hoc test reveals that overall all of the soap dispensers receive significantly different femininity scores ($M_{SD1}=16.4, M_{SD2}= 24.5, M_{SD3}= 40, M_{SD4}= 50, M_{SD5}= 58.4$). However, there is an interaction between age and occupation groups suggesting that the relationship between roundness and femininity depends on age and occupation $[F(4, 260) = 2.74, p< .05, \eta^2=.04]$. The relationship between roundness and femininity is also found in the 3d
The relationship is linear \( F(1, 72) = 161.4, p < .01, \eta^2 = .69 \). Overall, femininity scores of soap dispensers 1, 7 and 8 are significantly different and soap dispensers 1 and 2 and sd-8 and 9 are similar (\( M_{SD1} = 16.4, M_{SD6} = 25.5, M_{SD7} = 39.8, M_{SD8} = 56, M_{SD9} = 64 \)). However, there are differences in femininity scores between gender \( F(4, 260) = 5.72, p < .01, \eta^2 = .08 \) and age groups \( F(4, 260) = 2.83, p < .05, \eta^2 = .04 \). Moreover, a three-way interaction suggests that the relationship between roundness and femininity depends on age, gender and occupation in 3d manipulation condition for soap dispensers \( F(4, 260) = 2.43, p < .05, \eta^2 = .03 \).

\textit{Elegance}

No significant relationship is found between roundness and elegance in 2d manipulation condition for hard drives \( F(4, 288) = 447.7, p = .58, \eta^2 = .01 \). All hard drives received statistically significantly similar elegance scores (\( M_{HD1} = 37.5, M_{HD2} = 43.3, M_{HD3} = 40.8, M_{HD4} = 43.6, M_{HD5} = 40.7 \)) regardless of the level of roundness. However, a relationship does exist in the 3d manipulation condition for hard drives \( F(4, 288) = 11.05, p < .01, \eta^2 = .01 \) which is linear \( F(1, 72) = 25.39, p < .01, \eta^2 = .26 \). 8 are found to be similar (\( M_{HD1} = 37.5, M_{HD6} = 45, M_{HD7} = 46.3, M_{HD8} = 51.1, M_{HD9} = 62 \)).

A post hoc test reveals that hard drives 1, 8 and 9 received significantly different elegance scores whereas hard drives 1, 6 and 7 and hd-6, 7 and Elegance and roundness are not found to be related in either the 2d manipulation \( F(4, 288) = 1.06, p = .37, \eta^2 = .01 \) or the 3d manipulation conditions \( F(4, 288) = 1.12, p = .34, \eta^2 = .01 \) for soap dispensers. Mean scores of elegance are not significantly different from each other for both the 2d (\( M_{SD1} = 36.3, M_{SD2} = 42.5, M_{SD3} = 42.5, M_{SD4} = 42, M_{SD5} = 44.6 \)) and the 3d manipulation conditions (\( M_{SD1} = 36.3, M_{SD6} = 44.4, M_{SD7} = 43.8, M_{SD8} = 40.8, M_{SD9} = 43 \)). Results are summarized in Figure 43.
Figure 43 Elegance scores of hard drive and soap dispenser prototypes in both 2d and 3d manipulation conditions. Note: Only hard drives in 3d manipulation condition present significant relationship between roundness. Scores with different letters are statistically significantly different at $\alpha=0.05$ level between different levels of roundness. Means with same letter are not significantly different. Letters A & B series are associated with the 2D manipulation; X & Y series are associated with the 3D.

Results from study on form and meaning in context

Participants were also asked to consider these prototypes in context. ‘High-techness’ for hard drives, and ‘high-endness’ for soap dispensers were points of interest.

Results suggest that there is a relationship between roundness of the hard drives and the perception of high-techness in the 2d manipulation condition $[F(4, 288) = 19.37, p < .01, \eta^2 = .21]$ which has a linear relationship $[F(1, 72) = 28.19, p < .01, \eta^2 = .28]$. Overall, scores of hard drives-1, 3, and 4 are significantly different whereas hard drives-1 and 2 and hd-4 and 5 are not ($M_{HD1} = 64, M_{HD2} = 61.4, M_{HD3} = 53.5, M_{HD4} = 465.6, M_{HD5} = 39.8$). Similarly, roundness and high-techness are related in the 3d manipulation condition for hard drives $[F(4, 288) = 3.12, p < .01, \eta^2 = .04]$ with a linear trend $[F(1, 72) = 4.31, p < .05, \eta^2 = .05]$. 
However, none of the hard drives are significantly different in their high-techness scores ($M_{HD1} = 64$, $M_{HD6} = 66.2$, $M_{HD7} = 70.5$, $M_{HD8} = 69.4$, $M_{HD9} = 74.2$).

Roundness and high-endness are found related in the 2d manipulation condition for soap dispensers [$F(4, 288) = 7.33, p < .01, \eta^2 = .09$]. The relationship presents a significant linear relationship [$F(1, 72) = 11.23, p < .01, \eta^2 = .13$]. A post hoc test reveals that soap dispensers-1 and 3 have significantly different high-endness scores whereas soap dispensers-1 and 2 and sd-1, 3, 4, and 5 are similar ($M_{SD1} = 62.5$, $M_{SD2} = 63.5$, $M_{SD3} = 56.1$, $M_{SD4} = 51.3$, $M_{SD5} = 48.8$). There is a relationship between roundness and high-endness in 3d manipulation condition for soap dispensers [$F(4, 288) = 9.03, p < .01, \eta^2 = .11$] which is linear [$F(1, 72) = 13.81, p < .01, \eta^2 = .16$]. Overall, soap dispensers-1 and 7 receive significantly different high-endness scores whereas soap dispensers-1 and 2 and sd-2, 3, 4, and 5 have similar high-endness scores ($M_{SD1} = 62.5$, $M_{SD6} = 53$, $M_{SD7} = 47.3$, $M_{SD8} = 44.5$, $M_{SD9} = 42.2$). Results are presented in Figure 44.

Figure 44 In context scores of hard drive (high-techness) and soap dispenser (high-endness) prototypes in both 2d and 3d manipulation conditions.

Note: Scores with different letters are statistically significantly different at $\alpha=0.05$ level between different levels of roundness. Means with same letter are not significantly different. Letters A &B series are associated with the 2D manipulation; X & Y series are associated with the 3D.
An overall preference score for each prototype in both the 2d and 3d manipulation conditions are used to explore relationship between roundness and preference. Frequency values of each prototype are weighted depending on their preference order. Prototypes that were chosen as first choices were weighted more compare to those preferred as a third choice. The sum of these weighted scores was used as an overall preference score for each prototype.

Results suggest that the preference of hard drives appears related to roundness in both the 2d and 3d manipulation conditions. Except for hard drive-2 (with 25% roundness), when increments of roundness increase, the overall preference scores of hard drives in 2d manipulation condition decreases. On the other hand, while roundness increases, preference scores of hard drives in 3d manipulation condition increases. The preference trends for the 2d and 3d manipulation appear to be contradictory for hard drives.

Overall, preference scores of soap dispensers in the 2d and 3d manipulation conditions are similar. Results suggest that soap dispensers-2 and 6; sd-3 and 7 (soap dispensers which have 25% and 50% roundness) are preferred slightly more often than others. Results are illustrated in Figure 45.

![Preference scores](https://via.placeholder.com/150)

Figure 45 In-context scores for hard drive and soap dispenser prototypes in both 2d and 3d manipulation condition.
Correlations between meanings

Meaning scores for each participant of each prototype is used to explore overall correlations. The data was converted into a stacked format, which resulted n=365 cases for the 2d and 3d manipulation conditions. Pearson correlation coefficients were computed5.

Results regarding meanings for hard drives are summarized in Table 6 (2d manipulation condition) and Table 7 (3d manipulation condition). Overall in the 2d manipulation condition, safeness does not have any correlation with any other meanings. Seriousness is found to have a strong, positive correlated with aggressiveness, coldness, hardness, and masculinity whereas it shows a strong, negative correlation with playfulness, fun and femininity. There is a strong, positive correlation between aggressiveness and coldness, hardness, and masculinity; however, aggressiveness is found to be negatively correlated with femininity. Results reveal that coldness present a strong, positive correlation with hardness and masculinity; while it has a negative correlation with softness, playfulness, fun, and femininity. Warmness is found to have a strong, positive correlation with softness, playfulness, fun, and femininity whereas it has a strong, negative correlation with hardness. There is a strong, positive correlation between softness and playfulness, fun, and femininity and a negative correlation with hardness and masculinity. Hardness is found to be positively correlated only with masculinity. It has a strong, negative correlation with playfulness, fun, and femininity. Playfulness has a very strong, positive correlation with fun and femininity and a negative correlation with masculinity. There is strong, positive correlation between fun and masculinity and a positive correlation with femininity. Femininity is found to be strongly, negatively correlated with masculinity. Elegance is not correlation with any other meaning. Table 6 presents the correlations for the meaning extracted from the 2d manipulation condition for hard drives.

5 Correlations that are significant and between .20 to .29 correspond with weak; .30 to .39 is considered moderate; .40 to .69 is strong and .70 and higher is considered very strong correlation between to meanings.
Table 6 Correlation between meanings in 2D manipulation for hard drive prototypes

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** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Bold values indicate strong and very strong correlations.

Considering the 3d manipulation condition, safeness is not to be found correlated with any other meanings. Seriousness has strong, positive correlation with aggressiveness, coldness, hardness, and masculinity. Similarly, there is strong, positive correlation between aggressiveness and coldness, hardness and masculinity. Coldness is strongly, positively correlated with hardness and masculinity. Warmness has a strong positive correlation with softness, playfulness, fun and femininity and has a negative correlation with hardness. A strong positive correlation is found between softness and playfulness, fun and femininity; however, softness has a negative correlation with hardness. There is strong positive correlation between hardness and masculinity while there is a negative correlation with playfulness, fun, and femininity. Playfulness, fun and femininity are found to be strongly positive correlated. Femininity and masculinity are negatively correlated. Table 7 illustrates correlation results from 3d manipulation condition for hard drives.
Table 7 Correlation between meanings in 3D manipulation for hard drive prototypes

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**Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
** Bold values indicate strong and very strong correlations

Correlations between meanings for soap dispensers in the 2d manipulation condition are presented in Table 8. Safeness is not found to be correlated with any other meanings. Seriousness has a strong positive correlation with aggressiveness, coldness, hardness, and masculinity and a strong negative correlation with softness, playfulness, and femininity. There is a strong positive correlation between aggressiveness and coldness, hardness, and masculinity. Aggressiveness has a strong negative correlation with softness and femininity. Coldness is strongly positively correlated with hardness and masculinity. Warmness has a strong and positive correlated with softness, playfulness, fun and femininity and a negative correlated with hardness. A strong correlation is found between softness and playfulness, fun and femininity. Softness has strong negative correlation with hardness and masculinity. There is a strong positive correlation between hardness and masculinity, and a negative correlation with playfulness, fun and femininity.

Playfulness has a strong, positive correlation with fun and femininity and a negative correlation with masculinity. Fun has a strong and positive correlation with femininity and a
negative correlation with masculinity. Femininity is found negatively correlated with masculinity, and elegance is not strongly correlated with any other meanings.

Meaning correlations extracted from soap dispensers in the 3d manipulation condition are presented in Table 9. Results reveal that safeness does not present a strong correlation with any other meanings. Seriousness has a strong positive correlation with aggressiveness, coldness, hardness, and masculinity and a strong negative correlation with softness, playfulness, fun and femininity. There is strong and positive correlation between aggressiveness and coldness, hardness, and masculinity. Aggressiveness has a strong negative correlation with softness, playfulness, fun and femininity. Coldness has strong positive correlation with hardness and masculinity and a negative correlation with warmth, softness, playfulness, fun, and femininity. There is strong positive correlation between warmth and softness, playfulness, fun, and femininity. Warmth has a strong negative correlation with hardness and masculinity. Softness is found to be positively correlated with playfulness, fun and femininity and negatively correlated with hardness and masculinity. There is a strong correlation between hardness and masculinity while hardness has a strong negative correlation with playfulness, fun and femininity. A very strong correlation is found between playfulness and fun. Playfulness is also strongly positively correlated with femininity. There is a strong negative correlation between playfulness and masculinity. Fun has a strong positive correlation with femininity and a negative correlation with masculinity. Masculinity is strongly negatively correlated with femininity. Elegance is not correlated with any other meanings.
| Table 8 Correlation between meanings in 2D manipulation for soap dispenser prototypes |
|-------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                                                  | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  |
| 1.Safe                                           |     |     |     |     |     |     |     |     |     |     |     |     |
| 2.Serious                                        |     |     |     |     |     |     |     |     |     |     |     |     |
| 3.Aggressive                                     |     |     |     |     |     |     |     |     |     |     |     |     |
| 4.Cold                                           |     |     |     |     |     |     |     |     |     |     |     |     |
| 5.Warm                                           |     |     |     |     |     |     |     |     |     |     |     |     |
| 6.Soft                                           |     |     |     |     |     |     |     |     |     |     |     |     |
| 7.Hard                                          |     |     |     |     |     |     |     |     |     |     |     |     |
| 8.Playful                                       |     |     |     |     |     |     |     |     |     |     |     |     |
| 9.Fun                                            |     |     |     |     |     |     |     |     |     |     |     |     |
| 10.Masculine                                     |     |     |     |     |     |     |     |     |     |     |     |     |
| 11.Feminine                                      |     |     |     |     |     |     |     |     |     |     |     |     |
| 12.Elegant                                       |     |     |     |     |     |     |     |     |     |     |     |     |

**Correlation is significant at the 0.01 level (2-tailed).**

* Correlation is significant at the 0.05 level (2-tailed).

**Bold** values indicate strong and very strong correlations.

| Table 9 Correlation between meanings in 3D manipulation for soap dispenser prototypes |
|-------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                                                  | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  |
| 1.Safe                                           |     |     |     |     |     |     |     |     |     |     |     |     |
| 2.Serious                                        |     |     |     |     |     |     |     |     |     |     |     |     |
| 3.Aggressive                                     |     |     |     |     |     |     |     |     |     |     |     |     |
| 4.Cold                                           |     |     |     |     |     |     |     |     |     |     |     |     |
| 5.Warm                                           |     |     |     |     |     |     |     |     |     |     |     |     |
| 6.Soft                                           |     |     |     |     |     |     |     |     |     |     |     |     |
| 7.Hard                                          |     |     |     |     |     |     |     |     |     |     |     |     |
| 8.Playful                                       |     |     |     |     |     |     |     |     |     |     |     |     |
| 9.Fun                                            |     |     |     |     |     |     |     |     |     |     |     |     |
| 10.Masculine                                     |     |     |     |     |     |     |     |     |     |     |     |     |
| 11.Feminine                                      |     |     |     |     |     |     |     |     |     |     |     |     |
| 12.Elegant                                       |     |     |     |     |     |     |     |     |     |     |     |     |

**Correlation is significant at the 0.01 level (2-tailed).**

* Correlation is significant at the 0.05 level (2-tailed).

**Bold** values indicate strong and very strong correlations.
Meaning scores for each participant of each prototype are converted into a stacked format in SPSS (2013) and a proximity matrix is generated. In pathfinder network, \( r = \infty \) and an allowable path length of \( p = n-1 \) (\( p=11 \) for 12 meanings) are preferred (Schvaneveldt et al., 1985).

Proximity data for the 2d and 3d manipulation conditions for hard drives is entered simultaneously. The Pathfinder network included 12 nodes for each meaning with a total of 17 links among them. 35% of these links are shared between the 2d and 3d manipulation conditions and are found to be significantly similar (\( p< .01 \)). Overall, it can be inferred that the network structure presents three sub-networks. Seriousness, masculinity, aggressiveness, and hardness can be considered as one sub-network with greater weight scores. On the other hand, warmthness, softness, safeness, femininity, and playfulness comprise another sub-network; while playfulness, femininity, fun and elegance form another sub-network. Meanings in these sub-networks can be considered highly associated with each other. Also, the overall network structure presents polarity between sub-networks established around hardness and softness. Hardness appears as a central node since it is a shared node in both the 2d and 3d manipulation conditions and has at least 3 links with other meanings within the sub-network of which it is a part. Softness may be considered as a central node particularly in the 2d manipulation condition as may femininity be a central node for the 3d manipulation condition. Elegance and seriousness establish a simple chain with a weak link and connecting these two polar sub-networks to each other. Coldness and warmthness like hardness and softness appear to have a distal relationship. Although there is a distant relationship between masculinity and femininity, the distance apart is not as great as it is for coldness and warmthness or as far as the distance between hardness and softness. Playfulness and fun present very strong close relationship. The Pathfinder analysis for hard drives can be found in Figure 46.

A Pathfinder network was also created for soap dispensers. Similar to hard drives, the networks of 2d and 3d manipulation conditions of soap dispensers Overall the pathfinder network for soap dispensers has 12 nodes with total 14 links, 64% of these links are shared.
Figure 46 Pathfinder network of meanings in 2d and 3d manipulation conditions for hard drives.

Note: Numbers next to links indicate the weight of the links between two connected meanings. Lower numbers indicate less psychological distance and greater link weights between meanings. Central node is presented in bold.

between both manipulation conditions. These two networks are found significantly similar \((p<.01)\). In this case, masculinity, hardness and aggressiveness comprise a sub-network at one end of the network; while playfulness, warmthness, softness, femininity, safeness, and fun establish another sub-network at other end of the network. This may suggest a bipolar structure due to the meanings clustered in these two sub-networks. Seriousness, elegance and femininity create a chain structure and connect these two sub-networks. Seriousness and femininity appear as central nodes indicating that these meanings are individually associated with their surrounding meanings (e.g. seriousness relates independently to coldness, masculinity and elegance). Overall, coldness and warmthness; hardness and softness are found to have distant relationships. Although masculinity and femininity are far apart from each other, they are closer than coldness and warmthness and closer than hardness and softness. The Pathfinder network is presented in Figure 47.
Figure 47 Pathfinder network of meanings in 2d and 3d manipulation conditions for soap dispensers. Note: Numbers next to links indicate the weight of the links between two connected meanings. Lower numbers indicate less psychological distance and greater link weights between meanings. Central node is presented in bold.

**Video analysis**

Interviews were video recorded in order to explore strategies that participants used when they attribute meaning on prototypes during experiment two. Two video files (hard drives and soap dispensers) were created for each participant. There were total of 146 video files (each files is 6 to 8 minutes long). However, 12 video files were eliminated due to quality and technical issues during interviews with 6 participants. Two reviewers (both PhD students in design) analyzed the video footage independently using the coding scheme generated from a study conducted by Csikszentmihalyi and Eugene (1981) and researcher’s notes from the first experiment (see Appendix 4 for details of coding scheme and the description of each code — strategy). Reviewers were asked to count the codes (strategies) for each meaning, when the codes appeared during the interviews b using the coding table (see Appendix 5). An intracl
correlation coefficient (ICC)\textsuperscript{6} was calculated between the two reviewers’ scores for each participant and each prototype category (hard drives or soap dispensers). Video recordings of participants, whose ICC scores were below 0.7, were analyzed in a second round of video coding by the same two reviewers (together). Rankings of reviewers with 0.7 and higher ICC scores were averaged and the frequency of each strategy is reported for the final analysis. Overall, results for each meaning and the difference between age and occupation groups are illustrated in circle diagrams. Descriptive occurrences of meaning attributions strategies are defined as rarely, infrequently corresponds to 0 to 10%, seldom 10 to 20%, often 20 to 40%, frequently 40 to 50% and very frequently, heavily, mostly and dominantly more than 50%.

**Hard drives**

Participants rely on the physical qualities of the hard drives when they attributed safeness (47%) (see Figure 48). Sharper corners and edges are found to be dangerous and therefore unsafe. Participants often tended to consider the hard drive in context (whether hard drive

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\textsuperscript{6} ICC is a reliability test in statistics that measures inter rater agreement or consistency. It compares variability of different rankings of the same participant with the total variation for all rankings and participants. ICC values corresponds to: 0 to .5 poor agreement; .5 to .6 fair agreement; .6 to .7 moderate agreement; .7 to .8 strong agreement; .8 and above indicates very strong agreement (Cohen & Cohen, 1983).
drops, falls, tips in certain environment) when think of their safeness level (24%). Utilitarian features of hard drives are seldom determinant for their safeness 13%. Moreover, participants prefer to make associations (7%) in order to attribute safeness to hard drives.

Physical qualities are frequently preferred when attributing seriousness to hard drives (40%). Also, the utility of the hard drives (whether it looks like it can do the job) are often concerns of participant (20%). They also think about the hard drives in context (e.g. hard drives sit on the table of user) when they attribute seriousness (10%). Participants tend to make associations when they evaluate the seriousness of hard drives (e.g. it looks like a toy). Interactions (8%) and intrinsic qualities (8%) are considered infrequent as a strategy when attributing seriousness to hard drives (see Figure 49).

Participants use physical qualities as a cue to assign aggressiveness to hard drives (48%). Utilitarian features of the hard drives are seldom favored as well (13%). Participants refer to person-like characteristics (it seems like a good person/naive children etc.) when they describe their evaluation strategy for aggressiveness (11%). Associations (7%), interaction (7%) and contextual considerations also played infrequent roles when attributing aggressiveness to hard drives (see Figure 50).

Coldness is associated with physical qualities of hard drives (45%). The coldness of hard drives is described referring to interaction terms such as whether the hard drive is approachable or something they can easily hold (21%). Intrinsic qualities, such as uniqueness, precision, crafty-ness, and beautiful look are used often when attributing coldness to hard drives (11%). Participants also make associations (hard disk looks like an ice cube)(10%). Intrinsic qualities (7%) and personality (5%) is rarely preferred when talking about the coldness of hard drives (see Figure 51).

Physical qualities are frequently preferred when describing warmth of hard drives (38%). However, interaction terms are used often (21%). Warmness is considered whether hard drives are inviting or if they make participant feel nice when they touch them. Intrinsic qualities appear seldom (10%). Other strategies, such as associations (6%), utilitarian features (5%), in-context consideration (5%), and personality (4%) are rarely observed when participants’ attribute warmth to hard drives (see Figure 52).
Figure 49 Distribution of strategies that participants preferred when attributing ‘seriousness’ to hard drives.

Figure 50 Distribution of strategies that participants preferred when attributing ‘aggressiveness’ to hard drives.
Figure 51 Distribution of strategies that participants preferred when attributing ‘coldness’ to hard drives.

Figure 52 Distribution of strategies that participants preferred when attributing ‘warmness’ to hard drives.
Softness is very frequently associated with physical qualities (edges, corners, roundness, lines etc.) (62%). Interaction terms (touch, approach, hold etc.) are often used when attribution softness to hard drives (17%). Intrinsic qualities (8%), associations (5%) and in-context considerations (4%) are rarely used for softness (see Figure 53).

Strategies used when attributing hardness resemble those used for softness. Participants heavily rely on the physical qualities of the hard drives when attributing hardness (67%). Physical qualities happen to be the dominant strategy for hardness. Interaction terms are rarely used (9%). Utilitarian features (sturdiness, structured-ness, compactness etc.) are also favored by participants (8%). Associations (7%), personality (4%), in-context considerations (3%) are rarely preferred when attributing hardness (see Figure 54) for hard drives.

Playfulness is often described using physical qualities of hard drives (35%). Interaction terms (e.g. make me use/play/roll it) are also boldly used (20%). Participants tend to consider hard drives in-context (who would use it, where he/she would use it) when describing playfulness of hard drives (14%). Playfulness is seldom described by making associations to other products (11%). Participants also consider utilitarian features (10%) and intrinsic qualities (8%) of hard drives when attributing playfulness to hard drives (see Figure 55).

Participants rely on physical qualities (31%) and use interaction terms (24%) when they attribute fun to hard drives. Intrinsic qualities are also favored often (14%). Fun is found related to utilitarian features of hard drives (11%). Participants tend to make associations to describe fun in hard drives (11%). Moreover, hard drives are considered in context (whether hard drive fits in certain environment or certain style) when describing fun (see Figure 56). It is essential to highlight that in this case strategies are used almost equally and there is no strongly dominant strategy for attributing fun to hard drives.

Physical qualities appear as a dominant strategy when attributing masculinity to hard drives (65%). Associations are often used when describing masculinity for the hard drives (e.g. some of them looks like a male body) (17%). Also, participants tend to consider in context situations such as when a hard drive is only designed for males (7%). Intrinsic qualities are rarely used for masculinity (5%) (see Figure 57).
Figure 53 Distribution of strategies that participants preferred when attributing ‘softness’ to hard drives.

Figure 54 Distribution of strategies that participants preferred when attributing ‘hardness’ to hard drives.
Figure 55 Distribution of strategies that participants preferred when attributing ‘playfulness’ to hard drives.

Figure 56 Distribution of strategies that participants preferred when attributing ‘fun’ to hard drives.
Similar to masculinity, participants dominantly rely on physical qualities when assigning femininity to hard drives (69%). Associations are also used for femininity—in this case participants tend to consider resemblance of the female body or female products (12%). Interaction terms (6%), in-context considerations (6%), and intrinsic qualities (6%) are rarely preferred when attributing femininity to hard drives (see Figure 58).

Elegance is frequently related to physical qualities (slickness, harshness etc.) (39%), and intrinsic qualities (simplicity, sophistication, pleasing etc.) (37%). Participants refer to other products and make associations when evaluating elegance (10%). In-context considerations are also rarely made (whether the hard drive fits in an elegant office environment or not) (6%) (see Figure 59).

*Soap Dispensers*

Physical qualities of soap dispensers were heavily related to safeness (50%). Participants considered physical qualities and in-context consideration together (23%). They imagined the soap dispenser in a sink or on a surface where it can tip over and fall. Utilitarian features are also favored (17%) when attributing a meaning of safeness. Participants relied on the relationship between the body and the pump to indicate whether it will do the job correctly or not. Other strategies such as interaction terms (5%) and associations (4%) rarely preferred (see Figure 60).

Although participants mostly rely on physical qualities (39%) when attributing seriousness to soap dispensers they often use other strategies. They often consider soap dispensers in context (who would use it where we can see it) for seriousness (16%). Utilitarian features are also used (11%). Associations (10%), interaction terms (8%), intrinsic qualities (8%) and personality (7%) are also used when describing the seriousness for soap dispensers (see Figure 61).

Aggressiveness and physical qualities are very frequently related (50%). Soap dispensers with sharp corners are found to be highly aggressive. Participants preferred to use person-like characteristics to describe aggressiveness (13%). Utilitarian features (11%), interaction terms (7%), associations (7%), and intrinsic qualities (6%) also used (see Figure 62).
Figure 57 Distribution of strategies that participants preferred when attributing ‘masculinity’ to hard drives.

Figure 58 Distribution of strategies that participants preferred when attributing ‘femininity’ to hard drives.
Figure 59 Distribution of strategies that participants preferred when attributing ‘elegance’ to hard drives.

Figure 60 Distribution of strategies that participants preferred when attributing ‘safeness’ to soap dispensers.
Figure 61 Distribution of strategies that participants preferred when attributing ‘seriousness’ to soap dispensers.

Figure 62 Distribution of strategies that participants preferred when attributing ‘aggressiveness’ to soap dispensers.
Participants rely on physical qualities of soap dispensers when describing coldness (49%). They also often prefer to use interaction terms (24%). Personality (whether the soap dispenser has a characteristic such as an easy-going person) is also favored (8%). They tend to make associations with other products to describe coldness of soap dispensers (8%). Intrinsic qualities (7%) and in-context considerations (4%) are rarely used when attributing coldness to soap dispensers (see Figure 63).

Warmness is mostly described with interaction terms for soap dispensers (39%). Physical qualities are also frequently preferred as a cue (36%). Participants perceive soap dispenser that fit in their hand due to the size and form to be more approachable and therefore warmer. Associations are made when describing warmness (11%). Intrinsic qualities (6%), in-context considerations (4%), and utilitarian features (3%) are rarely used when attributing warmness to soap dispensers (see Figure 64).

Physical qualities are heavily used when attributing softness to soap dispensers (62%). Soap dispensers with rounded edges and corners are found to be very soft. Interaction terms are also preferred (20%). Soap dispensers that they want to approach, reach and touch are softer. Associations (5%), contextual considerations (5%), and utilitarian features (4%) are rarely used when attributing softness to soap dispensers (see Figure 65).

Strategies used for attributing hardness to soap dispensers are similar to those for softness. Participants heavily rely on the physical qualities of soap dispensers when describing hardness (62%). They also used interaction terms to describe hardness (17%). Soap dispensers with sharp and crisp corners are described as bulky and less comfortable in the hand and therefore very hard. Other strategies such as associations (7%) and in-context considerations (3%) are rarely preferred (see Figure 66).

Playfulness is often described using physical the qualities of soap dispensers (37%). Interaction terms (soap dispensers that can tip are found more playful) are preferred when describing playfulness (19%). Participants also tend to make associations (11%) or consider utilitarian features (10%). Contextual considerations (8%) are rarely made (8%) when attributing playfulness to soap dispensers (see Figure 67).
Figure 63 Distribution of strategies that participants preferred when attributing ‘coldness’ to soap dispensers.

Figure 64 Distribution of strategies that participants preferred when attributing ‘warmness’ to soap dispensers.
Figure 65 Distribution of strategies that participants preferred when attributing ‘softness’ to soap dispensers.

Figure 66 Distribution of strategies that participants preferred when attributing ‘hardness’ to soap dispensers.
Strategies for attributing meanings of playfulness and fun are similar. Participants tend to use cues from physical qualities when they describe fun in soap dispensers (30%). Interaction terms are also often used (22%). They make associations (e.g. toy-likeliness, brick like look) when they find fun in soap dispensers (13%). Intrinsic qualities (12%), in-context considerations (12%), and utilitarian features (10%) are also favored. Results suggest that participants equally utilize these strategies when attributing fun to soap dispensers (see Figure 68).

Masculinity is heavily determined by physical qualities of soap dispensers (61%). Soap dispensers with sharp corners and edges are reported to be more masculine. Associations are made when describing masculinity (19%). Contextual considerations (7%), personality (5%), intrinsic qualities (4%), and utilitarian qualities are used rarely when attributing masculinity to soap dispensers (see Figure 69).

Similar to masculinity, participants are found femininity and physical qualities highly related (64%). They occasionally rely on associations when describing the femininity of soap dispensers (14%). Interaction terms are seldom used (10%). Contextual considerations (6%) and intrinsic qualities are rarely revealed when describing the femininity of soap dispensers (4%) (see Figure 70).

Elegance of soap dispensers is mostly extracted from intrinsic qualities (whether the soap dispensers look different and unique, or whether they are pleasing) (38%). Physical qualities also used often to evaluate the elegance of soap dispensers (31%). Participants seldom prefer to consider soap dispensers in context in order to comment on their elegance (13%). Associations are seldom made when attributing elegance to soap dispensers (11%) (see Figure 71).

There is no pattern of difference between age and occupation groups in terms of strategies participant prefer when attributing meanings to these prototypes. However, it appears that their non-designers rely on physical qualities more than designers. Older and youngers present similarity in their strategies. Also, participants almost never tend to make memory associations when describing meanings for these prototypes, which suggests they either have no memories about these type of products or they basically do not need for recalling memory.
Figure 67 Distribution of strategies that participants preferred when attributing ‘playfulness’ to soap dispensers.

Figure 68 Distribution of strategies that participants preferred when attributing ‘fun’ to soap dispensers.
Figure 69 Distribution of strategies that participants preferred when attributing ‘masculinity’ to soap dispensers.

Figure 70 Distribution of strategies that participants preferred when attributing ‘femininity’ to soap dispensers.
Figure 71 Distribution of strategies that participants preferred when attributing ‘elegance’ to soap dispensers.

**Final Evaluation of Experimental Study Two**

Participants were asked to evaluate the tasks in experiment two. They were first asked whether it makes sense to attribute meanings to prototypes (hard drives and soap dispensers) or not during the experiment. All participants but one thought it made sense to add meaning to prototypes experienced during the experiment. Participants mostly found that ranking prototypes was a difficult task (3% rated the task as very easy, 7% as easy, 25% as somehow easy, 5% as neutral, 42% as somehow difficult, and 18% as difficult). They indicated that experiencing prototypes in context (high-tech and high-end) were relatively easy tasks (17% rated the tasks as very easy, 29% rated as easy, 24% rated somehow easy, 11% as neutral, and 19% rated somehow difficult). Finally, participants found experiment two overall as somehow easy (11% rated this as very easy, 21% rated as easy, 29% rated as somehow easy, 15% as neutral, 19% somehow difficult, and 5% as difficult).
3.5 Discussion

Results from experiment two are able support the findings from experiment one and answer some of the research questions. There is a pattern in the participants’ answers. Objects that are at the extreme ends with 0% or 100% roundness also receive extreme meaning scores even though prototypes do not show drastic topological differences unlike experiment one. Prototypes in the middle increment of roundness (50%) receive average meaning scores similarly prototypes close to extremes (25% and 75% roundness) receive meaning scores close to extremes. It can be inferred that prototypes in extreme roundness and closer are more likely associated with meanings more clearly compare to 50% roundness. Except for a few instances, the relationship between meanings and roundness is quadratic, which suggests that a change in roundness leads to a rapid change in the meaning scores.

Safeness presents a positive relationship to roundness. Regardless of whether it is a hard drive or a soap dispenser, when prototypes become rounder, they are perceived as safer. Seriousness on the other hand is perceived in an opposite manner. The rounder prototypes is less serious they are found. Results reveal a similar trend for aggressiveness. Participants find prototypes with sharp and crisp corners to be more aggressive than those with rounded corners. Similarly, prototypes with less roundness are found to be colder whereas prototypes with high roundness are found to be warmer. Although some participants consider coldness and warmness as related to temperature, some prefers to think of these meanings as approachability and inviting. Softness presents a parallel trend to warmness. The rounder the prototype is, the softer it is perceived. Hardness shows an opposite trend to softness. The rounder the prototype is, the less hard it becomes. Even though the physical quality of the surface hardness was the same for all prototypes, differences were observed which could be attributed to the manipulation conditions in form. Playfulness and fun were found to be very similar meanings. Prototypes with high roundness are found to be both more playful and fun. Masculinity and femininity are found to have opposite trends. Prototypes with sharp and crisp corners and edges are found to be more masculine and less feminine compare to those with high roundness. Elegance is found to be related to roundness for hard drives in the 3d manipulation condition. Prototypes in this group manipulated in roundness for both faces of surfaces; therefore, they begin look slicker and thinner (even though the thicknesses were the
same among all prototypes) when roundness increased. Considering the trends in technological devices such as hard drives, the results of elegance for this group is not surprising. However, elegance is not found to be related to roundness for any other conditions for the other prototypes. This suggest that for some products roundness might have high impact in perception of elegance whereas some participants might need more information than just roundness in order to attribute elegance. Overall, prototypes in the 3d manipulation received higher safeness, warmth, softness, playfulness, fun and femininity scores, and lower seriousness, aggressiveness, coldness, hardness and masculinity scores compared to prototypes in the 2d manipulation since prototypes in the 3d manipulation received roundness in both faces of surfaces and look more rounded.

Meanings that might be related to product gender such as seriousness, masculinity, softness and femininity receive significantly different scores between gender and age groups. Participants’ genders within different age groups might have particular idea about these meanings. Moreover, seriousness, masculinity and femininity scores differ based upon participants’ gender, age and occupation. There is no difference in meaning scores between designers and non-designers except in a few situations. For example, (e.x. seriousness, masculinity and fun were different between occupation groups for hard drives in 2d manipulation conditions. Similarly coldness and playfulness for the 2d manipulation and softness and warmth for the 3d manipulation condition for soap dispensers present differences between occupation groups.

Hardness and perhaps both softness and femininity are central nodes for hard drives suggesting that hardness has an independent relationship from surrounding meanings. Femininity and seriousness appears to central nodes for soap dispensers. Considering that these meanings, hardness and softness, are at the opposite ends of networks (for both hard drives and soap dispensers), they are promising to begin with in order to design for meaning.

It can be inferred that there are three types of meanings in terms of strategies that participants prefer. The first sets of meanings are the ones that participants rely heavily upon the physical qualities of prototypes. These meanings include aggressiveness, softness and hardness, masculinity and femininity. For the second sets of meanings, include coldness, warmth, and elegance, participants use two dominant strategies. In this case, participants
frequently refer to physical qualities in combination with interaction terms for coldness and warmness. While participants refer to intrinsic qualities and physical qualities for elegance. Safeness, seriousness, playfulness, and fun establish the third set meanings in which participant allocate many strategies roughly equally.

**GENERAL CONCLUSIONS**

*Implications of FMAP*

The second chapter of this study introduced a framework of meaning attribution to product forms (FMAP). The main goal of this framework was to map the literature on meaning in product design in order to provide a better understanding of the reviewed theories, other frameworks and their connections. The literature was reviewed, discussed and visualized to generate the FMAP. This effort enhanced our understanding of product form and its meanings.

This study used the FMAP to generate research questions focusing on relationship between physical qualities and meanings. Figure 72 illustrates the procedure used in this study in order to isolate the complexity of the FMAP and generate research questions. The procedure suggests that if one controls the “Physical and Geometrical Qualities” of an object, and intents to observe influence on “Perceptual Qualities”, this may create expected “Meanings” through certain attention and concerns channels as long as one controls “Representational features” (memory involvement, branding etc.). It is believed that FMAP has the potential to support future research and help generate researchable questions in the area of design for meaning. The framework also has practical implications. Product form has an impact on the success of the product in market place (Bloch, 1995). A product form should contain much information about the product. Product form is the embodiment of perceived value (Cooper, 2001). FMAP suggests that meaning development occurs across the design process and therefore should be managed (Crilly et al., 2004; Ulrich & Eppinger, 2011).
Design research generally focuses on usability issues, sometimes product engineering testing and sometimes product appearance; however, there are very few investigations that focus on meanings. FMAP and the experiments in this study suggest a method for researching design for meaning.

**Theoretical Contributions**

This study contributed to the body of knowledge regarding the effects of physical qualities of product forms on attributed meanings. It is too early to propose, however, that these results support that there is a pattern in relationship between physical manipulation and meaning. The relationship very frequently presents that perceptions of meanings are triggered by greater magnitude (positive or negative depending on meaning) on roundness due to quadratic relationships in the data. This concept is similar to Weber’s law (Coren et al., 2004), which proposes that noticeable difference between two stimuli (in our case level of roundness) is proportional to the magnitude of subjective sensitivity. However, this proportion for meanings, if exists, is not clear yet and it may or may not fit in the Weber fraction (Coren et al., 2004).
Participants, particularly in experiment two, were able to perceive stable changes in roundness when attributing meaning. A quadratic relationship suggests that minor change in physical quality (roundness) might lead to a greater impact on meanings; therefore, designers should pay extra attention to details in product form in order to clearly communicate their intended meaning. Changing the physical qualities of product form drastically might lead to misinterpretations.

Bottom-up perception processes most likely drive, softness and hardness, masculinity, femininity and aggressiveness. These meanings are found strongly correlated. Moreover, participants relied on heavily on physical qualities when they attribute these set of meanings to prototypes. It can be inferred that meanings for which participants allocated physical qualities, and some of the interaction terms as strategies, are more likely subject to Affordance Theory. Softness particularly appears to be influenced by product form more than any other meaning. Although the physical qualities for surface hardness were the same for all objects and prototypes, participants were still able to find high rounded examples to be softer. This might be the reason softness and hardness was found to be central nodes.

When a meaning has more than one connotation for users, it is more likely to be perceived as complex. For examples although some participants considered coldness and warmness meanings as a temperature (which was same amongst all objects and prototypes), the rounder ones are found to be warmer and less cold.

Elegance and seriousness appear to be the bridge between two polar opposites in the pathfinder networks. Seriousness is found to be closer to masculinity, hardness and coldness whereas elegance is found to be closer to seriousness and femininity. These terms are maybe constructed by social forms and are more likely subject to Product Semantics; therefore, the meaning attribution process of these meanings might require higher cognitive effort.

Overall, participants allocated more than one strategy equally in order to attribute meanings of safeness, seriousness, playfulness, and fun. In order to make sense of these meanings for the objects and prototype, participants sought more information and thought more in depth, considering many possibilities in once. Therefore, this set of meanings might be subject to top-down perception processes. Results are promising that involvement of cognitive processes might depend on the meaning that one seeks. It can be inferred that
bottom-up and top-down approaches are more likely used simultaneously when attributing meaning to objects and prototypes.

Methodological Contributions

This study was suggests using real prototypes and product in design research instead of just photographs of products. It was assumed that participants tend to think and talk aloud more while experiencing objects and prototypes when compared to photographs. In the first experiment, the preference and familiarity test was conducted to check to see if there was any familiarity effect on participants’ rankings of meanings. Initial results of this phase suggested that no mean centralization was needed since participants highly preferred the uniqueness. Also, using unipolar meaning scales instead of bipolar was found to be beneficial. Although there were meanings perceived to be strong opposites (softness and hardness) or very similar (playfulness and fun), there were meanings that co-occurred (masculinity and femininity). The co-occurrence of meanings resulted in closer proximities between these meanings in pathfinder network compare to the distance between opposite meanings. Also, it is believed that presenting bi-polar scales assumes that the two ends in the scale are complete opposites and does not promote participants’ interpretations. Last, interviews with participants helped reveal the reasoning behind their rankings for each meaning and prototype category. Overall, the tasks used in the experiment are found somehow easy.

Practical Contributions

Designers are trained to manipulate product form during their education. They are equipped with tools and techniques to shape product form; however, the meanings that might evolve around a certain product form are tacit knowledge. For example, design students are generally told that when drawing a square it should look like a square not rectangle. If the drawing looks to be somewhat in between a square and rectangle, it is not representative. Results of this study suggest that when manipulations of physical qualities of forms are in between extremes (e.g. the drawing is being between a square and rectangle or objects have 50% roundness), the forms are perceived with many meanings and therefore, they are more likely to be confusing.
Although there is no clear pattern found regarding meaning differences between gender, age and occupational groups, they do frequently exist. Therefore, research efforts focusing on design for meaning should not avoid or ignore these differences.

The results of this study may inform companies that are generally driven by technology and manipulate their product form depending on capabilities of their technology in their new models (e.g. smart phone producers). However, companies should note that changes in product form might result in change in meanings and if this is the case it might result in a change in brand perception. Therefore, product form should be managed related to the brand values and personality. This study presents a framework and an experimental case study from which companies can benefit to understand design for meaning.

This study provides evidence and support for stereotypical expectations from product form (when things become rounder, they are perceived to be feminine). Thus the study support common strategies explaining why stereotypicality occurs (e.g. female products are rounded; female body looks curved — hence the association).

It can be inferred from Pathfinder results that when designing for meaning focusing on softness and hardness, femininity and seriousness (central nodes) might help achieve assignments of more complex meanings such as elegance and fun. These meanings are more likely behaving as a transition between physical tangible qualities and perceived intangible qualities. Also, strategies allocated by the participants for each meaning can be used as guidance for designers and design researchers. For example, if a designer wants to achieve seriousness for a product, results suggest the designer should: consider the product in context (who would like to use this product, where the user of this product would like to place this product); focus on utilitarian features (so that the product should do the job and perform its function correctly and precisely); research products that target users currently use in order to make associations to seriousness (what a serious product would look like for particular user); and investigate how the target user interacts with products they perceived as serious.

This study improves our understanding about the relationship between contextual meanings (e.g. high-techness) and physical qualities. Results suggest that the relationship is likely product category depended. Products that are technology related — in this case hard drives — presented a strong relationship in participants’ rankings. The sharper the edges and
the corners on the prototype — the more high-tech it is found in 2d manipulation condition. The reason might be that these features offer precision and sophistication in product form. However, the more rounded the prototype is in 3d manipulation, the more high-tech it is found. In this case, roundness is more likely influence the perception of the size of the prototype. Many participants stated that the rounder hard drives are smaller and eventually look slicker and smaller and therefore, it contains higher technological equipment in it. On the other hand, the high-endness of soap dispensers presented similar results in both the 2d and 3d manipulation conditions. The rounder the soap dispenser is perceived as less high-end. Highly rounded soap dispensers might be perceived as toy-like or for children and therefore less serious and less high-end.

**Limitations**

Participants were recruited from NC State University community. Most had attained higher education and therefore might have a different perception of the meanings of product forms. Also, the number of participants in both age groups was not perfectly balanced (particularly in experiment one). Also, results should be interpreted in the American cultural context.

Prototypes used in experiments were highly controlled. Even though the order of presentation of the items to participants was randomized at some point participants might begin to compare them. Since the only difference between the objects and prototypes were the roundness, the effect of the physical qualities might appear more important than it is in natural settings. Moreover, participants might rank roundness instead of meanings. However, if this were the case, results would be similar across all meanings.

This study only assessed three types of products (abstract objects, hard drives and soap dispensers). Results suggest that 12 meanings presented similar pattern across these products however, there are differences in context meanings (high-techness and high-endness). It is expected that the product category play a role in context measurements. Moreover, this study focused on only one type of manipulation (roundness) in two conditions (2d and 3d). This is a small number considering the other physical qualities that a product contains. It is expected that size, texture, materials and color play roles when designing for meaning.
**Future studies**

Roundness can be applied in three ways to objects. This study included only two types (2d and 3d) of roundness. Studies regarding the application of style of roundness may reveal differences in meanings.

The current study introduced objects and prototypes to participants all at one time. Participants were exposed to these objects for short period. Therefore, results are limited to those based upon their first impression. A carefully design longitudinal study with real products might reveal changes in meaning over time.

There were 12 meanings used in the study. Future studies might explore other product meanings and investigate determinants of these meanings. Also, strategies with which these meanings are associated are not yet clear.

Cognitive involvement in the meaning attribution process also is not yet clear. Thus future studies might include time spent and response time when attributing meaning on products.

Finally, cultural differences in the meaning attribution process may also be explored in future studies.
REFERENCES


APPENDICES
### Appendix 1. Descriptive Statistics for two-dimensional manipulation and meanings-
Abstract Objects

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N=37, 17 male, 20 female; 18-30 young n=25, 31-70 older n=12; designer n=19, non-designer n=18.
Appendix 1b. Descriptive Statistics for three-dimensional manipulation and meanings-
Abstract Objects

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Appendix-2b. Descriptive Statistics for three-dimensional manipulation and meanings – Hard drives

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<td>15.4</td>
<td>27.8</td>
<td>18.4</td>
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<tr>
<td>Elegant</td>
<td>37.5</td>
<td>32.8</td>
<td>44.9</td>
<td>29.6</td>
<td>46.3</td>
</tr>
</tbody>
</table>

*N = 73, 37 male, 36 female, 18-30 young n=44, 31-70 older n=29; designer n=31, non-designer n=42*
### Appendix 3. Descriptive Statistics for two-dimensional manipulation and meanings – Soap Dispenser

<table>
<thead>
<tr>
<th></th>
<th>Dispenser 1 [0% Rounded]</th>
<th>Dispenser 2 [25% Rounded]</th>
<th>Dispenser 3 [50% Rounded]</th>
<th>Dispenser 4 [75% Rounded]</th>
<th>Dispenser 5 (Sphere)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safe</strong></td>
<td>Mean 36.9 SD 35.9</td>
<td>Mean 51.6 SD 33.1</td>
<td>Mean 54.7 SD 28.4</td>
<td>Mean 55.1 SD 29.1</td>
<td>Mean 50.0 SD 30.2</td>
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<tr>
<td><strong>Serious</strong></td>
<td>Mean 78.5 SD 25.7</td>
<td>Mean 69.4 SD 25.3</td>
<td>Mean 50.5 SD 25.6</td>
<td>Mean 42.0 SD 25.1</td>
<td>Mean 30.6 SD 24.4</td>
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<tr>
<td><strong>Aggressive</strong></td>
<td>Mean 75.0 SD 26.5</td>
<td>Mean 57.9 SD 28.9</td>
<td>Mean 40.4 SD 26.9</td>
<td>Mean 31.7 SD 22.8</td>
<td>Mean 25.8 SD 23.3</td>
</tr>
<tr>
<td><strong>Cold</strong></td>
<td>Mean 66.5 SD 33.8</td>
<td>Mean 57.2 SD 29.2</td>
<td>Mean 48.4 SD 23.9</td>
<td>Mean 34.6 SD 24.1</td>
<td>Mean 28.9 SD 23.1</td>
</tr>
<tr>
<td><strong>Warm</strong></td>
<td>Mean 15.6 SD 18.9</td>
<td>Mean 21.6 SD 16.5</td>
<td>Mean 29.7 SD 20.9</td>
<td>Mean 39.3 SD 24.1</td>
<td>Mean 45.8 SD 26.2</td>
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<tr>
<td><strong>Soft</strong></td>
<td>Mean 9.0 SD 13.3</td>
<td>Mean 19.7 SD 19.4</td>
<td>Mean 29.3 SD 24.0</td>
<td>Mean 41.0 SD 25.6</td>
<td>Mean 47.1 SD 24.0</td>
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<tr>
<td><strong>Hard</strong></td>
<td>Mean 82.5 SD 23.4</td>
<td>Mean 69.6 SD 26.8</td>
<td>Mean 56.5 SD 26.1</td>
<td>Mean 43.0 SD 24.2</td>
<td>Mean 39.9 SD 26.0</td>
</tr>
<tr>
<td><strong>Playful</strong></td>
<td>Mean 15.4 SD 21.7</td>
<td>Mean 20.4 SD 17.8</td>
<td>Mean 30.2 SD 21.8</td>
<td>Mean 44.1 SD 25.1</td>
<td>Mean 57.3 SD 27.5</td>
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<tr>
<td><strong>Fun</strong></td>
<td>Mean 17.0 SD 21.3</td>
<td>Mean 22.4 SD 18.6</td>
<td>Mean 31.6 SD 20.6</td>
<td>Mean 43.5 SD 25.7</td>
<td>Mean 61.0 SD 23.4</td>
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<tr>
<td><strong>Masculine</strong></td>
<td>Mean 81.1 SD 19.6</td>
<td>Mean 69.2 SD 24.4</td>
<td>Mean 49.0 SD 23.8</td>
<td>Mean 40.6 SD 24.3</td>
<td>Mean 31.0 SD 22.1</td>
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<tr>
<td><strong>Feminine</strong></td>
<td>Mean 16.4 SD 22.2</td>
<td>Mean 24.5 SD 21.4</td>
<td>Mean 40.0 SD 23.7</td>
<td>Mean 49.9 SD 21.5</td>
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<td><strong>Elegant</strong></td>
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<td>Mean 42.0 SD 26.4</td>
<td>Mean 44.6 SD 26.3</td>
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*N = 73, 37 male, 36 female; 18-30 young n=44, 31-70 older n=29; designer n=31, non-designer n=42*
### Appendix 3b. Descriptive Statistics for three-dimensional manipulation and meanings – Soap Dispenser

<table>
<thead>
<tr>
<th></th>
<th>Dispenser 1</th>
<th>Dispenser 6</th>
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<td>Mean</td>
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<td>18.9</td>
<td>26.2</td>
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<td>13.3</td>
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<td>Hard</td>
<td>82.5</td>
<td>23.4</td>
<td>62.0</td>
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<tr>
<td>Playful</td>
<td>15.4</td>
<td>21.7</td>
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<td>Fun</td>
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</tr>
</tbody>
</table>

*N = 73, 37 male, 36 female; 18-30 young n=44, 31-70 older n=29; designer n=31, non-designer n=42*
Appendix 4 Coding scheme used during the video analysis in experiment two

FORM AND MEANING STUDY VIDEO CODES AND THEIR DESCRIPTIONS

FREQUENCY

If participants mention something that fits the description of codes stated below:
Enter the frequency, how many times they mentioned certain code: ‘1’, ‘2’ etc.

HARD TO ANSWER

If participant spends sometime before they answer a question or phrase that the meaning was hard to convey, then enter ‘1’ for “Hard to answer” section.

PHYSICAL QUALITIES

Did the participant mention about physical qualities of the objects such as, roundness, harshness of the lines, color, texture, weight etc.

(Edges, corners, sturdy, structure, roundness, proportions, unstable, tipping, bulky, slick, breakable, fragile, compact)

I think it is because of the harsh edges…
Roundness had an effect on it…
Softness of the corners…

MEMORY

Did the participant use, tell any memory related story or event to describe this specific object? This includes sentimental associations. Some examples:

This gives me memories of….
It connects me with….
It Reminds me of…..
It belongs to my grandma...
ASSOCIATION

Did the participant make any associations with something to describe this specific object?

It reminds me of my country...
It looks like (another object)...
It was gifted me from a friend (so it is associated with your friend)

INTRINSIC QUALITIES

Did participant mention about crafting of this specific object? The precision of the object hand-made or mass-produced. Did participant mention about uniqueness of this specific object?

(Expensive look, uniqueness, Emotional connection, precision, refined, higher generation/version look, cute, elegant, simple, pleasing, thoughtfulness, sophisticated, attractive, stylish)

This is one of a kind...
Object is physically unique…
I could never replace it...
This is rare....
It is different than others…
It looks cool..
It is interesting…

UTILITARIAN/FUNCTIONALITY

Did the participant describe this object somehow with its utilitarian features?
Did the participant mention what he/she would do with this object?
Object can be considered as convenient, time saving, money saving or energy efficient.
Statements on Usability, What one could do with it, durable, it does what it is suppose to do.

It tips over…
It can do (this and that)…
It might hurt someone
It would get the job done…

PERSONALITY

Did the participant describe this object as an embodying personal values, aspirations, goals, achievements, that are desired or sought after?
Did the participant describe this specific object as having the qualities of a person?

(Stronger, friendly, easy to hand out, being direct with you, attacking)

It is aggressive…
It is very conservative…
It looks very much like a nice person
It gave me confidence

INTERACTION

Did the participant phase any attempt to interact with an object? Did they mention what object tells them what to do with the object?

(Comfortable, relaxed, inviting, approachable, make me use it, stand off)

It is inviting…
It wants me to hold it…
I can do/play/roll with it….

CONTEXTUALITY

Was it contextual description?
Did the participant use environmental or contextual cues to describe the object?

If it drops, if we can play with it, who would buy/use it?

I see this objects in (specific environment)

I can imagine this objects in “Victorian style house” ...(modern kitchen etc.)

I would own this

It looked professional

It looks modern
Appendix 5 Coding table used during the video analysis in experiment two

<table>
<thead>
<tr>
<th>PARTICIPANT ID</th>
<th>PROTOTYPE</th>
<th>SAFE</th>
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<th>SERIOUS</th>
<th>MASCULINE</th>
<th>AGGRESSIVE</th>
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<th>ELEGANT</th>
<th>WARM</th>
<th>HARD</th>
<th>PLAYFUL</th>
<th>FEMININE</th>
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</tr>
</tbody>
</table>

Memory (M)  Association (A)  Intrinsic Qualities (Q)  Utilitarian Features (U)  Personality (Pe)  Contextual Description (C)  Interaction (I)  Physical Qualities (P)

Sample coding: $P^2 C Pe^3 = \text{Two times Physical quality, one time Contextual description and three times Personality}$