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WHAT IS FAMILIAR IS BEAUTIFUL: A NOVEL APPROACH INVESTIGATING THE RELATIONSHIP BETWEEN AESTHETICS AND PERCEIVED USE

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THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the College of Arts and Sciences at the University of Kentucky

By

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Lexington, Kentucky

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ABSTRACT OF THESIS

WHAT IS FAMILIAR IS BEAUTIFUL: A NOVEL APPROACH INVESTIGATING THE RELATIONSHIP BETWEEN AESTHETICS AND PERCEIVED USE

Objective: This study investigates the application of aesthetic principles to designed objects with which we interact, specifically looking at the impact of perceived function of the objects on perceptions of visual appeal. **Background:** Previous studies have demonstrated that a product's judged beauty or visual appeal is related to perceptions of its usability. Arguments have been put forward for both directions of causality leading to "what is beautiful is usable" and "what is usable is beautiful" hypotheses. Explanations for the relationship between usability and beauty judgments include stereotype effects, ecological explanations, and cognitive processing viewpoints. The current studies contribute to this debate by manipulating usability and aesthetic principles independently to determine whether well-established aesthetic principles are contingent on perceived function. **Method:** 248 participants were recruited for two experiments. In Experiment 1, participants viewed sixteen illustrations that varied in ways that frequently increase the beauty of objects (i.e., basic principles such as symmetry, balanced massing, curvature, and prototypicality) and rated their degree of visual appeal. In Experiment 2, participants rated the appeal of the same stimuli as in Experiment 1 but were primed by instructions describing the illustrations as either alternative designs for microwave control panels or designs of building façades. **Results:** Strong support for the aesthetic principles of symmetry and spatial massing, but not curvature, were found in both experiments. Participants generally preferred stimuli that were symmetrical and evenly massed (i.e., "balanced"). Additionally, the manipulation of a functional prime significantly interacted with several aesthetic principles that relate to the match between the supplied prime and the prototypicality of the stimulus for the primed class of objects. **Conclusions:** Aesthetic principles of symmetry and spatial massing can be considered very potent ways to influence a user's degree of perceived visual appeal that are resistant to specific use cases or situations. Other principles, such as curvature preferences, seem to be limited by the prototypicality of curvature for a primed class of objects. So when considering whether "what is beautiful is usable" or "what is usable is beautiful," the results from the current study demonstrate that it may be more appropriate to say "what is familiar is beautiful."

KEYWORDS: Aesthetics, Usability, Function, Beauty, What is beautiful is usable

Travis Miller Kent

Author's Signature

October 5th, 2017

Date

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Dedicated to Caroline and Terry Kent.

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Chapter 1: Introduction

Human factors engineers and usability researchers have recently been debating the relationship between users' judgments of aesthetic qualities of consumer products and their judgments of usability. Several studies have shown that objects rated as more beautiful are also more likely to be rated as more usable, leading to the popular tag line, "What is beautiful is usable" (Tractinsky, Katz, & Ikar, 2000). Other studies, however, have led researchers to infer the reverse relationship -- "What is usable is beautiful". In other words, the perceived usability of a product may affect perceptions of the product's beauty (Hassenzahl, 2004; Mahlke, 2007; Van Schaik & Ling, 2008). In the proposed study, we explore the effect of changes in usability on judgments of visual appeal. Unlike previous studies, however, we do not manipulate usability by altering visual characteristics of the target products, which may change other unintended stimulus qualities, but by priming participants with different functional sets (i.e., by changing the presumed purpose of the product). Our goal is to determine whether the match between form and function affects peoples' aesthetic judgments when they are instructed to focus only on their aesthetic responses.

Understanding the relationship between usability judgments and aesthetic judgments is important to usability professionals for several reasons. One concern is with the place of usability engineering in the product design cycle. For consumer products, industrial designers and marketing researchers are both charged with creating products that appear appealing. Usability specialists, however, focus on minimizing the errors and inefficiencies experienced by users. If users' aesthetic responses to a product change their actual performance or their performance self-assessments, then greater weight will be placed on aesthetics over usability principles when the two are in conflict. Usability researchers have also been concerned about the validity of usability self-report scales that are often used as part of formal usability testing, both in the lab and in the field. Are users unable to fully distinguish the two concepts? Or are rapid aesthetic responses causing halo biases that distort slower usability judgments? Finally, aesthetic responses to features in the natural (i.e., not human-made) world may serve as rapid and frequently reliable cues to the effort required to perform a task or to potential hazards associated with objects. The latter possibility suggests the importance of calibrating aesthetic characteristics and actual usability in designed products in order to provide users with accurate expectations of ease-of-use.

Before turning to a review of the human factors, human-computer interaction, and usability engineering research on the relationship of usability and aesthetic judgments, we will describe pertinent principles and theories from the psychological study of aesthetics. In particular, we will focus on basic aesthetic principles that describe the attributes of products that evoke perceptions of beauty in nature, art, and design. We will also discuss general theories of aesthetics that attempt to account for and integrate these varied aesthetic principles. Of particular interest, several aesthetic theories are consistent with the view that aesthetic judgments and usability judgments are based on many overlapping visual cues and are inextricably linked.

Aesthetic Research

Defining aesthetics. The research literature on aesthetics is characterized by different uses of the same or similar terms by different authors. The following definitions will be adopted for the purposes of the present research.

- Aesthetics: "The study of human minds and emotions in relation to the sense of beauty." (Palmer, Schloss, & Sammartino, 2013, p. 79)
- Aesthetic attributes: Attributes of stimuli that are correlated with judgments of beauty, for example, simple scene statistics and visual primitives, as well as emergent features such as symmetry and grouping. Interactions of physical features of the stimulus and the experience of the observer (e.g., familiarity and novelty) are also considered aesthetic attributes.
- Aesthetic principles: The predicted relationship between aesthetic attributes and aesthetic responses (e.g., symmetrical stimuli are more likely to be judged as beautiful than asymmetrical stimuli).
- Aesthetic responses: For the purposes of the present study, aesthetic responses will be limited to observers' judgments of beauty or visual appeal. More generally in the aesthetics literature, aesthetic responses also include emotional, physical, and unconscious responses associated with the conscious experience and appreciation of beauty.
- Classical aesthetics: Focuses on aesthetic principles related to the effect of attributes such as symmetry, clarity, and order. Classical principles have been recognized for hundreds of years (Lavie & Tractinsky, 2004)

- Expressive aesthetics: Focuses on aesthetic principles related to the effect of attributes such as creativity and originality (Lavie & Tractinsky, 2004)

Aesthetic Design Principles

Symmetry. One of the most salient and frequently studied aesthetic attributes is symmetry. Research has indicated that people tend to like objects and shapes that are more symmetrical than those that are not. This has been shown in simple dot configurations (Garner & Clement, 1963), graphic designs (Jacobsen & Höfel, 2002), and human faces (Grammer & Thornhill, 1994).

Curvature. Another aesthetic attribute that has shown a consistent direction of preference by observers is that of curvature. Research has shown that people tend to prefer objects with curved contours more than similar linear objects (Bar & Neta, 2006). Subsequent research has also shown that the preference for curves holds for both abstract and real-world objects (Silvia & Barona, 2009). Interestingly, in a study by Leder, Tinio, and Bar (2011), participants preferred curved contours in objects that were positive or neutral in emotional valence, but not in objects with negative valence such as bombs or snakes.

Prototypes and familiarity. Prototypical objects are representations of a class of objects, having the category's most common or typical features (e.g., a robin is a more prototypical bird than an ostrich). Prototypes are abstractions that may not be exactly like any specific object directly experienced by the observer. Familiarity, on the other hand, is generally used in the aesthetic literature to refer to a specific exemplar of a class of objects to which an observer has been repeatedly exposed.

Research has indicated a preference for images that are either familiar or prototypical. This preference can be seen in a variety of studies and examples. For instance, for objects that have familiar locations like bowls and celling fans, people tend to prefer images of these objects that place them in the most frequently experienced vertical locations, i.e. bowls were preferred towards the bottom of a frame and celling fans towards the top of a frame (Sammartino & Palmer, 2012). Likewise for size, individuals tend to prefer larger representations of typically large objects like elephants, and prefer smaller representations of small objects like insects (Konkle & Oliva, 2011; Linsen, Leyssen, Sammartino, & Palmer, 2011). Finally, people tend to find lower-level spatial properties that match the most frequent characteristics of natural scenes (e.g., more horizontal and vertical than oblique lines, and characteristic density gradients) as more appealing (e.g., Latto, Brain, and Kelly (2000)).

Although the above principles are often applied to art and design, we will use these principles to manipulate aesthetic responses of participants to instrumental objects. That is, we will attempt to replicate these aesthetic responses in the context of objects with specific, widely recognized functions.

Theories of Aesthetics

There are several theories that attempt to explain and integrate aesthetic principles such as those described above. These theories are particularly relevant to research relating aesthetics and usability because several explicitly link the principles to potential performance and survival benefits that are also associated with the same stimulus characteristics.

Prototype theory. Prototype theory espouses that people will have a preference for stimuli that are most representative of a given category. As discussed earlier, people show a preference for sizes and relative positions of stimuli that are more prototypical than other presented stimuli. Prototypes are the basis of expectancies about both where and what elements will appear in a visual array. Thus, prototypical forms can be more efficiently explored and identified.

Fluency theory. Fluency theory includes ideas from prototype theory and posits that individuals will prefer stimuli that are easier to process when compared to more resource-demanding alternatives. In addition to predicting a benefit for prototypical or familiar stimuli, fluency theory can explain why symmetrical images are preferred over less symmetrical ones. Symmetry from this perspective is a form of redundancy; it reduces the overall complexity (i.e., information load) of the stimulus while, in the terminology of information theory, it increases overall transmission security (Shannon & Weaver, 1949). Symmetrical stimuli are associated with more accurate/safe responses. In short, symmetry aids in comprehension and processing of objects (Garner & Clement, 1963). Additionally, fluency theory gives an explanation of preferences for prototypical scenes and objects as research has demonstrated that prototypes are processed faster and with less effort (Palmer et al., 2013; Posner & Keele, 1968).

Ecological theory. Finally, the ecological approach can also assist in understanding aesthetic preferences. In general, the theory assumes that humans prefer characteristics associated with objects that have historically supported survival and reproductive advantages. Preference for symmetrical objects may stem from potential benefits for selecting symmetrical foods and mates as symmetry is often a signifier for good health or absence of genetic defects. Likewise, humans show a preference for symmetrical faces (Grammer & Thornhill, 1994; Jones et al., 2001).

Ecological theory could also explain the pattern of preferences seen in contour and familiarity effects. Objects with sharp edges can be seen as more threatening and in turn, are less liked. Likewise, familiar objects may be generally less threatening. Objects or scenes that are not readily interpreted or recognized could signal a new and perilous situation.

Although there are other theories of aesthetic response in humans, the theories described above make it clear that researchers in this field believe there is a relationship between aesthetic responses and characteristics that, if considered in products, we would generally equate with usability. These characteristics include lack of complexity, use of redundancy, use of familiar design elements, predictable location of information sources, and easy detection of hazards (e.g., sharp edges). Thus, one possible explanation for the frequent correlations found between users' judgments of usability and beauty may be that these concepts share many overlapping attributes.

Usability Research

The discipline of human factors engineering has traditionally focused on human performance in complex, safety-critical domains such as aviation, process control, and military operations (Chapanis, Garner, & Morgan, 1949). The application of human factors methods and principles to consumer products and web design is more recent (Norman, 1988). The traditional applications necessitate a focus on safety, effectiveness, and efficiency; the more recent applications, often called "usability engineering," must also improve the satisfaction and pleasure users associate with particular products (Hancock, Pepe, & Murphy, 2005). Usability engineers quickly discovered that they needed to understand aesthetic design principles as well as principles of human performance.

What is beautiful is usable. Usability engineers began using self-report measures of beauty, attractiveness, and appeal as part of their routine product usability tests, along with standard outcome measures such as perceived usability, cognitive load, and objective measures of performance efficiency (Hancock et al., 2005). In a study comparing several automatic teller machine (ATM) interface designs, Kurosu and Kashimura (1995) noted the strong relationship between their research participants' ratings of usability and beauty. Participants' ratings were also compared to the designs' adherence to validated usability design principles (e.g., functional organization, familiarity). The authors found that participants' ratings of usability were more closely tied to their ratings of beauty than to the designs' adherence to actual usability design rules. Familiarity was the only usability principle that surpassed participants' ratings of beauty in the strength of its association with participants' usability ratings.

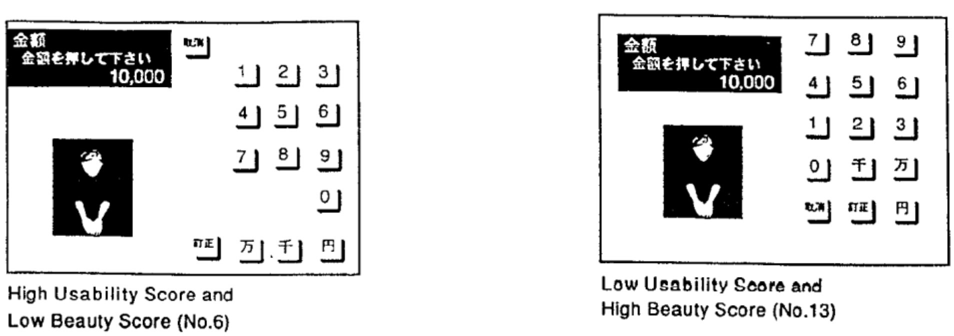


Figure 1.1 Example stimuli used in (Kurosu & Kashimura, 1995)

Concerned that the findings of Kurosu and Kashimura (1995) were particular to the aesthetic traditions of a specific culture, Tractinsky (1997) replicated the original Japanese study in Israel. The usability-beauty correlation was, in fact, cross-cultural. Tractinsky also independently manipulated the aesthetic and usability characteristics of ATM interface designs and found a reliable impact of visual appeal on participants' usability judgments (Tractinsky et al., 2000). Tractinsky's findings lead him to claim, "What is beautiful is usable," basing this tag line on social psychologists' research on the attractiveness halo effect, in which a person's attractiveness affects others' judgments of his/her personality traits, i.e., "What is beautiful is good" (Dion, Berscheid, & Walster, 1972).

A number of correlational and experimental studies followed the original work of Kurosu and Kashimura (1995) and Tractinsky (1997). Tables 1.1 and 1.2, showing results of correlational and experimental studies respectively, are adapted and updated from Tuch, Roth, HornbæK, Opwis, and Bargas-Avila (2012). Across studies, mean weighted correlations between beauty and usability ratings are .63. The studies mainly focus on design of websites and handheld digital devices (cell phones, mp3 players), and include both studies in which participant rated designs before and after actual use. The correlational studies clearly demonstrate that a relationship exists between the two type of ratings but says little about causality. Data from experimental studies indicate that manipulation of a design's aesthetic characteristics influences ratings of usability (r= .31). However, it also appears that manipulation of usability affects ratings of aesthetics (r= .26).

What is usable is beautiful. Based on the experimental work that attempts to independently manipulate the usability and visual appeal of product designs, some researchers have made the argument that it is at least as likely that "What is usable is beautiful" as it is that "What is beautiful is usable." (Tuch et al., 2012). For example, in a study utilizing mobile phones, Hamborg, Hülsmann, and Kaspar (2014) found that the manipulation of aesthetic attributes did not reliably impact usability judgments, although the manipulation of usability did influence aesthetic judgments. Four mobile phones were created as stimuli in a 2 (beauty) X 2 (usability) factorial design. Participants completed normal phone tasks like inputting a new contact into the address book and were asked to provide ratings of visual appeal and usability. Similar results supporting the importance of actual product usability in determining ratings of visual appeal have been obtained by other researchers investigating websites (Lee & Koubek, 2010; Tuch et al., 2012) and computerized phone books (Ben-Bassat, Meyer, & Tractinsky, 2006).

Figure 1.2 High and low aesthetic stimuli in Hamborg et al. (2014) study. Usability was manipulated by menu structure

Limitations of previous studies. The study of the impact of usability perceptions (and actual usability) on aesthetic judgments, as well as the study of the reversed relationship, faces a number of challenges. Tables 1.1 and 1.2 indicate that there was variability in the methods and stimulus materials used in the studies on this topic. Early studies used correlational methodologies while others used experimentation. Some studies only permitted participants to view pictures of products while others allowed them to actually use products. And the methods of manipulating aesthetic responses differed, with some studies varying product designs based on aesthetic principles and some simply selecting existing stimuli based on aesthetic responses (i.e., ratings). Furthermore, methods of measuring aesthetic responses are largely unstandardized, in part because different post-use surveys have become preferred for different types of products (Dumas & Salzman, 2006). Similarly, with respect to usability manipulations, some researchers manipulated ease-of-use by applying validated design principles and others selected products based on actual user performance.

Relatively few studies in this area have manipulated aesthetics properties of their stimuli based on aesthetic principles from the empirical aesthetics literature. An exception is a study by Sonderegger and Sauer (2010) who manipulate visual appeal by applying aesthetic principles involving texture, symmetry, and color. Most other studies use preexisting stimuli and use pilot study ratings of visual appeal to determine how to categorize the stimuli. Ben-Bassat et al. (2006) for example, created six stimuli, obtained aesthetic ratings for them, and selected the highest and lowest rated stimuli as their "high" and "low" aesthetic conditions. We see the post-design approach to selecting stimuli for these studies as limiting in that it does not allow us to determine whether the aesthetic principles derived from studies of art and simple stimuli (e.g., dot patterns) will generalize to predictions of the beauty of instrumental objects. Further, a careful understanding of the stimulus features that differentiate very appealing and unappealing stimuli will make it easier to make comparisons to the qualities that distinguish high and low usability products in the same study. This allows us to better understand the shared stimulus properties in usability and aesthetic principles that might predict when correlations between usability and beauty judgments will occur.

A related challenge with respect to creating stimuli for experimental studies is the difficulty of making products more or less usable without also changing attributes that may be related to aesthetics. Dissociating aesthetic and functional properties in real products can be challenging. As an example, in Figure 1.3, the electronic phone book on the right is the less appealing of the two; however, the design of the same phone book may also be less usable because the contrast between icons and background is also less strong. Researchers try to ensure that they have independently manipulated aesthetic attributes and usability attributes by performing post-design manipulation checks. However, statistically establishing that two stimuli are "equivalent" is problematic. In order to deal with the challenges of stimulus design in the proposed study, we will attempt to manipulate one of the two qualities (specifically, usability) through an instructional manipulation (i.e., a manipulation of functional sets) rather than attempting to create stimuli that clearly dissociate beauty and usability altogether. We recognize that our stimuli may vary along physical dimensions that can influence both usability and visual appeal, but we can still control the nature of this relationship by manipulating the participants' understanding of the implied tasks to be performed with the stimuli.

Another potential problem with many studies of the usability-beauty relationship is the manner in which participants are asked for their product judgments. Typically, participants make both usability and aesthetic judgments for several different products. It is well established that when faced with making multiple judgments about a single entity (e.g., rating multiple performance attributes of an employee, or multiple qualifications of a candidate) people will often use substitution heuristics (Kahneman & Frederick, 2002), perhaps as a way of making the task less demanding. The halo bias discussed earlier is one example of substitution in which an easier judgment about a person (e.g., attractiveness) is substituted for a harder one (e.g., is used to answer a question about professional competence). Rating both usability and beauty at the same time may increase participants' use of substitution strategies. Furthermore, performing multiple judgments in close proximity may result in simple interference errors, a common form of error in situations requiring divided attention across different stimulus properties (Reason, 1990). In either case, the impact of asking participants to make both ratings is to inflate their relationship. In the current study, we will attempt to limit the impact of the substitution heuristic and multi-attribute interference by having participants focus on only one judgment.

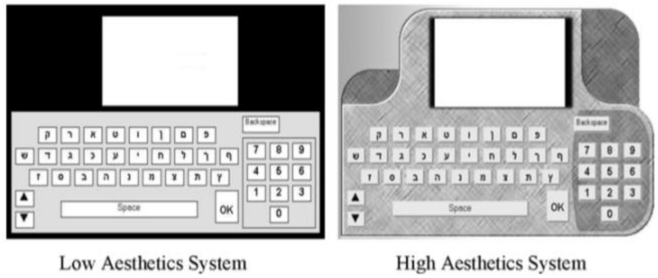


Figure 1.3 Low and high aesthetic stimuli in Ben-Bassat et al. (2006) study.

Furthermore, the current study was comprised of two experiments to further integrate research from empirical aesthetics and usability engineering. In the first experiment, we attempted to replicate aesthetic responses to stimuli that vary on the basis of established aesthetic principles. The purpose of the first study was to determine if the aesthetic principles of symmetry, spatial composition (specifically vertical massing), and curvature hold when applied to stimuli similar to those used to represent interface and architectural designs. The purpose of the second experiment was to determine whether participants when asked to focus on the visual appeal of the stimuli would be influenced by the functional nature of the object when they made judgments of visual appeal.

Table 1.1 Summary of correlational studies investigating the relationship between usability and aesthetics. Adapted from (Tuch et al., 2012)

Source	Product (task)	Correlation (r)	Usability Metrics	Aesthetic Metrics
Kurosu and Kashimura (1995)	ATM layouts (no usage)	pre-use: .59	"easy to use" (1 item)	beautiful (1 item)
Tractinsky (1997)	ATM layouts (no usage)	pre-use: .83 to .92	"easy to use" (1 item)	beautiful (1 item)
Ling and Van Schaik (2006)	Websites (information retrieval)	post-use: .49	DES-R (6 items)	aesthetics (1 item)
Hassenzahl (2004) study 1	MP3 player skins (passive viewing)	pre-use: .07	PQ (7 items)	beauty (1 item)
Hassenzahl (2004) study 2	MP3 player skins (usage scenarios)	pre-use: .14; post-use: .08	PQ	beauty (1 item)
Lavie and Tractinsky (2004)	websites (online shopping)	post-use: .68 to .78 (CA); .40 to .46 (EA)	created from factor analysis (4 items)	CA and EA (10 items)
Chawda, Craft, Cairns, Heesch, and Rüger (2005)	search tool (search task)	pre-use: .76; post-use: .71	SUS	self made (item list not disclosed)
Cyr, Head, and Ivanov (2006)	Mobile web pages (information retrieval)	post-use: .24 (PLS path coefficient)	PEOU (3 items)	self-made (4 items)
Hartmann, Sutcliffe, and De Angeli (2007)	websites (information retrieval)	post-use: .43	self-made (1 item)	self-made (1 item)
Quinn and Tran (2010)	cell phones (phone usage)	post-use: .50 to .53	SUS	self-made (7 items)

Abbreviations: CA = classical aesthetics (Lavie & Tractinsky, 2004); DES-R = display evaluation scale (Spenkelink, Besuijen, & Brok, 1993); EA = expressive aesthetics (Lavie & Tractinsky, 2004); HQI = hedonic quality identification (Hassenzahl, 2004); HQS = hedonic quality simulation (Hassenzahl, 2004); PEOU = perceived ease of use (Koufaris, 2002); PQ = pragmatic quality (Hassenzahl, 2004); SUS = system usability scale (Brooke, 1996)

Table 1.2: Summary of experimental studies investigating the relationship between usability and aesthetics. Adapted and updated from (Tuch et al., 2012)

Source	Product (task)	Main effects (η^2)*	UB metrics	AE metrics	UB factor	AE factor	MC (Cohen's f)*
(Tractinsky et al., 2000)	ATM layouts (ATM usage	AE on perceived UB (.037)	self-made (1 item)	self-made (1 item)	2 levels (system delays)	3 levels (placement of buttons)	UB: large (1.87) AE: large (2.37)
(Ben-Bassat et al., 2006)	digital phonebook (data entry)	AE on perceived UB (.189)[1] UB on perceived AE (.056)[1]	adapted[2] (4 items)	self made (3 items)	2 levels (number of keystrokes)	2 levels (visual design)	UB: large (3.50) AE: large (.79)[4]
Thüring and Mahlke (2007) study 2	simulated audio players (player usage)	trend AE on perceived UB (.034)	SUMI (sub dimensions)	CA or EA[3]	2 levels (navigation elements)	2 levels (different skins)	UB: medium (.30-.32) AE: medium (.37)
Thüring and Mahlke (2007) study 3	simulated audio players (player usage)	trend AE on perceived UB (.035)	SUMI (sub dimensions)	CA or EA[3]	2 levels (navigation elements)	2 levels (different skins)	UB: large (.73-1.00) AE: large (.81)
Mahlke and Thüring (2007)	simulated audio players (player usage)	trend AE on perceived UB (.035)	SUMI (sub dimensions)	CA or EA[3]	2 levels (navigation elements)	2 levels (different skins)	UB: large (.83) AE: large (.81)
Sonderegger and Sauer (2010)	mobile phones (various tasks)	AE on perceived UB (.035)	"attractive" (1 item)	"appealing" (1 item)	not manipulated	2 levels (high low attractiveness)[6]	UB: large (.75) AE: large (.71)
Lee and Koubek (2010)	websites (information retrieval)	AE on perceived UB (.167) UB on perceived AE (.141)	PSSUQ (8 items)	CA & EA (10 items)[5]	2 levels (content organization)	2 levels (color, layout, font)	UB: large (.77) AE: large (.81)
Hamborg et al. (2014)	mobile phones (various tasks)	UB on perceived AE (.056)	AttrakDiff2	beautiful (1 item)	2 levels (interface complexity)	2 levels (high/low aesthetics)	UB: large (.73) AE: large (.79)

Abbreviations: AE = aesthetics; CA = classical aesthetics (Lavie & Tractinsky, 2004); EA = expressive aesthetics (Lavie & Tractinsky, 2004); MC = manipulation check*;* PSSUQ = post-study system usability questionnaire (Lewis, 2002); SUMI = software usability measurement inventory (Kirakowski & Corbett, 1993); UB = usability. *effect sizes were not always reported in the original papers; [1]unclear which F-value goes with which main effect; [2] from (Lavie & Tractinsky, 2004); [3]not indicated which dimension was used; [4]data from a pilot study; [5]CA & EA were averaged and analyzed as a single scale; [6]Based off prior research by Ngo, Teo, and Byrne (2003)

Chapter 2: Experiment 1

Method

The purpose of Experiment 1 was to determine if the aesthetic principles of curvature, spatial massing, and symmetry would hold when applied to prototypical stimuli of control panels and building facades.

Table 2.1 Stimuli used in Experiments 1 & 2

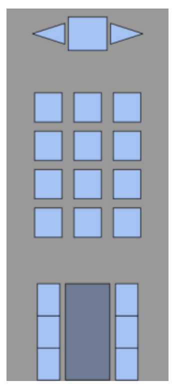
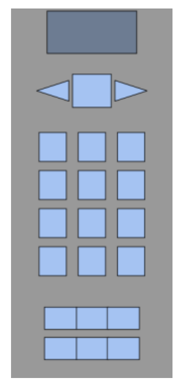
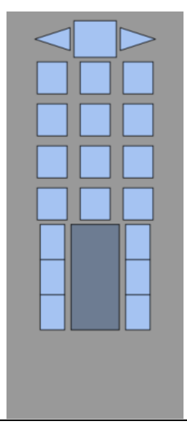
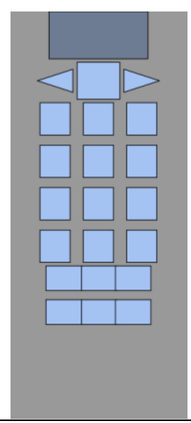
Design Manipulations	Based on Building Façade Prototype	Based on Microwave Control Panel Prototype
Symmetrical, angles, centered		
Symmetrical, angles, vertical bias		

Table 2.1 (continued)

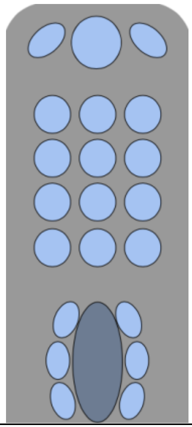
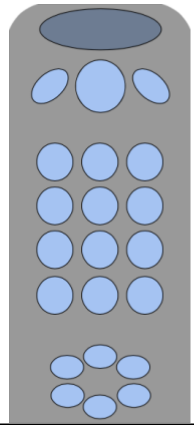
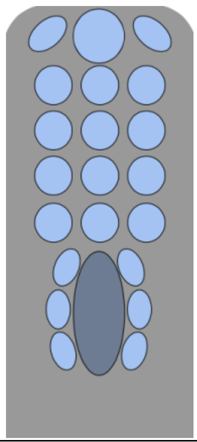
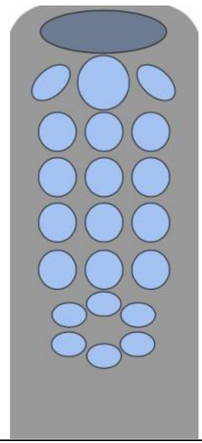
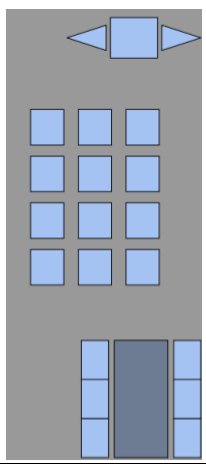
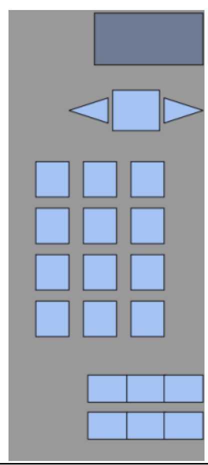
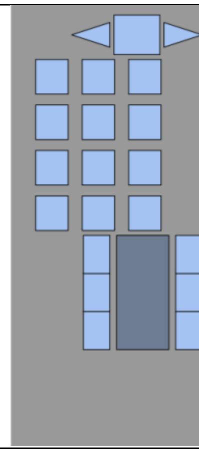
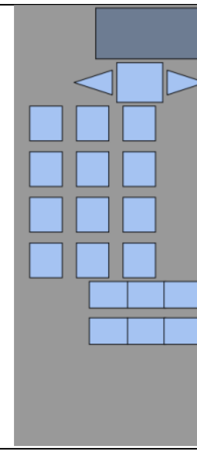
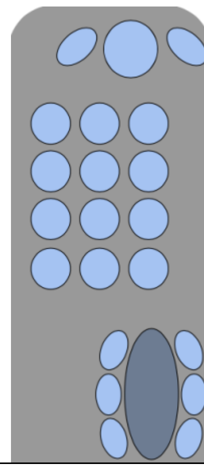
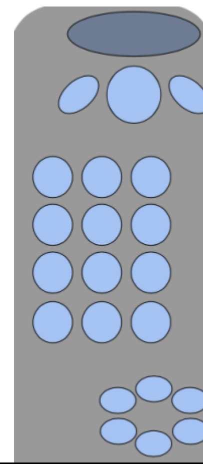
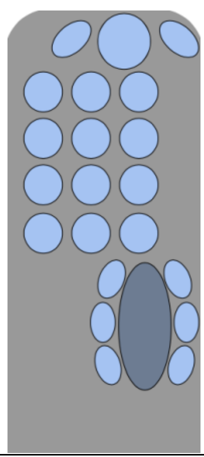
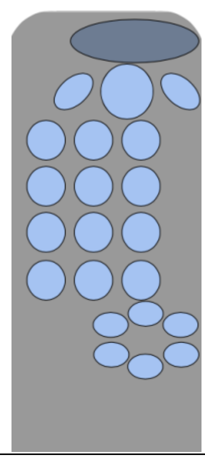
Symmetrical, curves, centered		
Symmetrical, curves, vertical bias		
Asymmetrical, angles, centered		

Table 2.1 (continued)

Asymmetrical, angles, vertical bias		
Asymmetrical, curves, centered		
Asymmetrical, curves, vertical bias		

Experimental Design. A within-subjects experimental design was utilized for the first experiment. Participants viewed a series of 16 geometric designs that vary in terms of the way 24 simple objects (e.g., circles, triangles, squares) are arranged within a vertical rectangular frame. Independent variables were symmetry (present or absent), curvature (use of circles and ovals vs. use of squares, triangles, and rectangles) and spatial composition (centered/balanced massing vs. massing in upper half of frame). The main dependent variables were ratings of visual appeal, with overall time to complete the session collected as a blocking variable for studies of individual differences.

Participants. 124 participants were recruited via Mechanical Turk (MTurk) (http://www.mturk.com). This number was determined by an *a priori* power analysis using effect sizes from early pilot data. Only participants that had a completion rate of 95% or higher on MTurk and had completed 500 previous MTurk studies were allowed to participate. Participants were given 15 minuets to complete the survey and upon completion were compensated $.50. The mean completion time for participants was four minutes.

Data collection. Data were collected and stimuli presented using the online survey software Qualtrics (http://www.qualtrics.com). Participants used their own laptop or desktop computers to access the Qualtrics survey.

Stimuli. As shown in Table 2.1, sixteen stimuli were created using Google Slides and Microsoft PowerPoint. Images consisted of 24 simple shapes placed on a vertical rectangle. Eight images were based on an initial arrangement of simple shapes that resembled a prototypical multi-story building. The remaining images were based on an arrangement of the same simple shapes to resemble a microwave control panel. Our hope, however, was that stimuli created from the microwave and building prototypes would be ambiguous enough that neither category would be evoked unless associated with a related prime. The two columns of Table 2.1 illustrate stimuli from the two prototypes. Different rows indicate the specific combination of the independent design variables (curvature, symmetry, and composition). Curvature was added by substituting circles/ovals for squares/rectangles and by contouring the top frame to have a gentle curve rather than a right angle. Composition was varied by either distributing the simple shapes throughout the rectangle or by compressing them into the upper part of the rectangle. Symmetry was manipulated by offsetting the groupings of objects in the stimuli to not be symmetrical to one another.

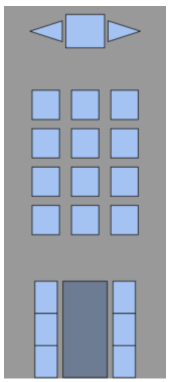
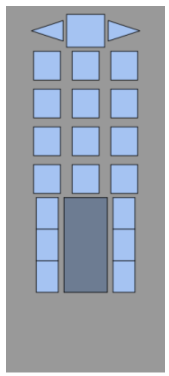
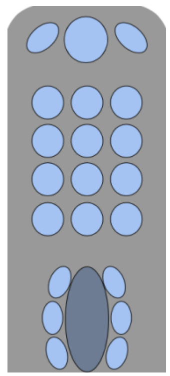
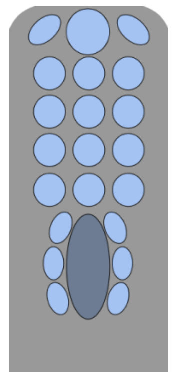
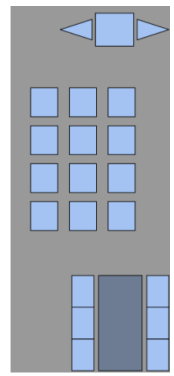
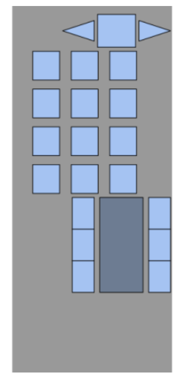
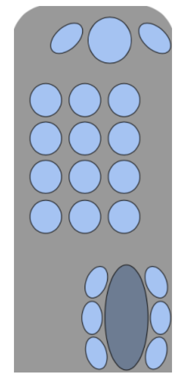
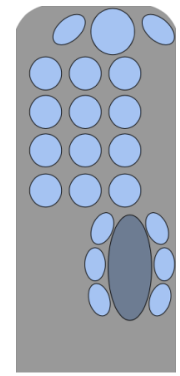
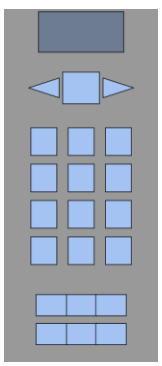
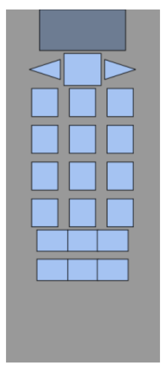
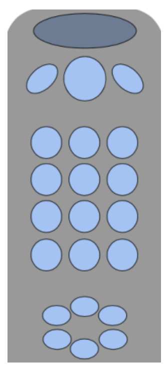
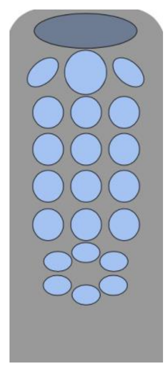
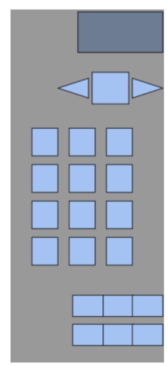
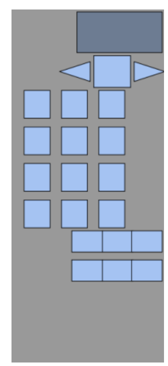
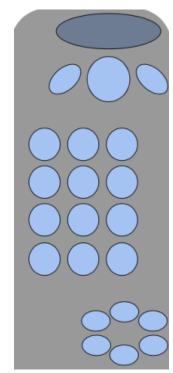
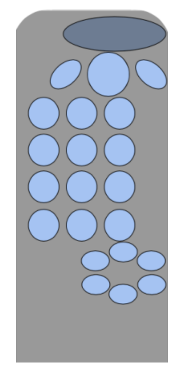
Procedure. Upon discovering the survey on the MTurk website, participants were offered a chance to read a brief description of the study and consent to participate. After consenting to participate, participants were presented with the following instructional message: “You are about to see a series of line drawings. We are interested in how visually appealing each drawing is to you. Please move the slider to indicate how much you like each design. We want your first impressions, so please make your judgments as quickly as possible.”

Stimuli were displayed to the participant one at a time in a random order. A 10-point rating scale (1 = very unappealing; 10 = very appealing) appeared underneath each stimulus. As soon as the participant moved the slider to indicate their ratings for a stimulus and clicked the ‘continue’ button, they were immediately presented with the next stimulus in the series. Upon completion of all of the image ratings, participants provided demographic information and answer open-ended questions about how they made their judgments.

Results

Data were submitted to two primary analyses. First, a 2 (symmetry) X 2 (massing) X 2 (curvature) X 2 (prototype) repeated-measures ANOVA was carried out to determine if any of the aesthetic principles previously mentioned significantly affected users' ratings of visual appeal. Second, when significant interactions were observed among aesthetic principles, post-hoc t-tests were carried out to isolate simple effects. Data from 124 participants were utilized from the total of 125 tested. One user was dropped because he or she failed to complete the survey. Table 2.2 shows the means and standard deviations of visual appeal scores for each of the 16 stimuli. Inspection indicates a trend toward preferences for symmetric, evenly-distributed stimuli. The results of the statistical analyses will be described in the context of each of the aesthetic principles.

Table 2.2 Descriptive statistics for stimuli in Experiment 1

Design Manipulations	Symmetrical, angles, centered	Symmetrical, angles, vertical bias	Symmetrical, curves, centered	Symmetrical, curves, vertical bias	Asymmetrical, angles, centered	Asymmetrical, angles, vertical bias	Asymmetrical, curves, centered	Asymmetrical, curves, vertical bias
Based on Building Façade Prototype								
Descriptive Statistics	M= 4.212 SD= 1.751	M= 4.009 SD= 1.83	M= 4.123 SD= 1.835	M= 4.083 SD= 1.765	M= 2.604 SD= 1.801	M= 2.252 SD= 1.739	M= 2.447 SD= 1.615	M= 2.265 SD= 1.766
Based on Microwave Control Panel Prototype								
Descriptive Statistics	M=4.219 SD= 1.792	M= 3.954 SD= 1.915	M= 4.452 SD= 1.815	M= 4.099 SD= 1.645	M= 2.465 SD= 1.807	M= 2.272 SD= 1.885	M= 2.699 SD= 1.737	M= 2.170 SD= 1.72

Symmetry. As expected, there was a reliable main effect of symmetry ($F\{1,123\}=191.78$; $p<.000$, $\eta^2=.609$), with symmetrical stimuli (M= 4.099, SD= 1.251) being preferred over asymmetrical stimuli (M=2.401, SD= 1.452). This manipulation did not significantly interact with any other variable, thus providing consistent and strong support for the classic aesthetic principle of symmetry.

Curvature. The aesthetics literature provides evidence that people tend to prefer curved objects over angular ones. However, there was not a significant difference between participants' ratings of visual appeal for curvature in the present study ($F\{1,123\}= 0.682$; $p>.4$). Curved stimuli received a mean rating of 3.296 (SD=1.267) and angular stimuli received a mean rating of 3.203 (SD= 1.383). The manipulation of curvature did interact, however, with the prototype of the design (i.e., those stimuli that were modeled after microwave controls vs. building facades) as discussed below.

Spatial Massing. The manipulation of massing of objects within the frame of the stimuli resulted in a reliable main effect on participants' ratings ($F\{1,123\}=36.089$; $p<.000$, $\eta^2=.227$). The stimuli with evenly distributed objects were more visually appealing (M=3.407, SD=1.180) than those stimuli with objects massed at the top of the frame (M=3.093, SD=1.231). Additionally, spatial massing significantly interacted with prototype as discussed below.

Prototypicality. As intended, there was no significant difference between users' ratings of visual appeal for stimuli generated to look like typical building facades (M=3.253, SD=1.191) and those generated to look more similar to typical microwave control panels (M=3.246, SD=1.196) ($F\{1,123\}= 0.029$; $p>.86$, $\eta^2<.00$). In other words, participants did not prefer microwave stimuli to buildings or vice versa overall. However, as mentioned previously, prototypicality did reliably interact with both spatial massing ($F\{1,123\}=5.359$; $p<.025$, $\eta^2=.042$) and curvature ($F\{1,123\}=6.823$; $p=.01$, $\eta^2=.053$) shown in figures 2.1 and 2.2 respectively.

As can be seen in Figure 2.1, participants rated the evenly spaced layouts of stimuli more visually appealing than those with elements massed at the top of the frame, but only significantly so for microwave prototypes ($t\{1,246\} = 2.64$; $p<.00$). Prototype building stimuli did not see as great an effect for spatial massing ($t\{1,246\} = 1.28$; $p=.2$). This might suggest that, when it comes to microwave control panels, users have less tolerance for violations to aesthetic principles than in building designs.

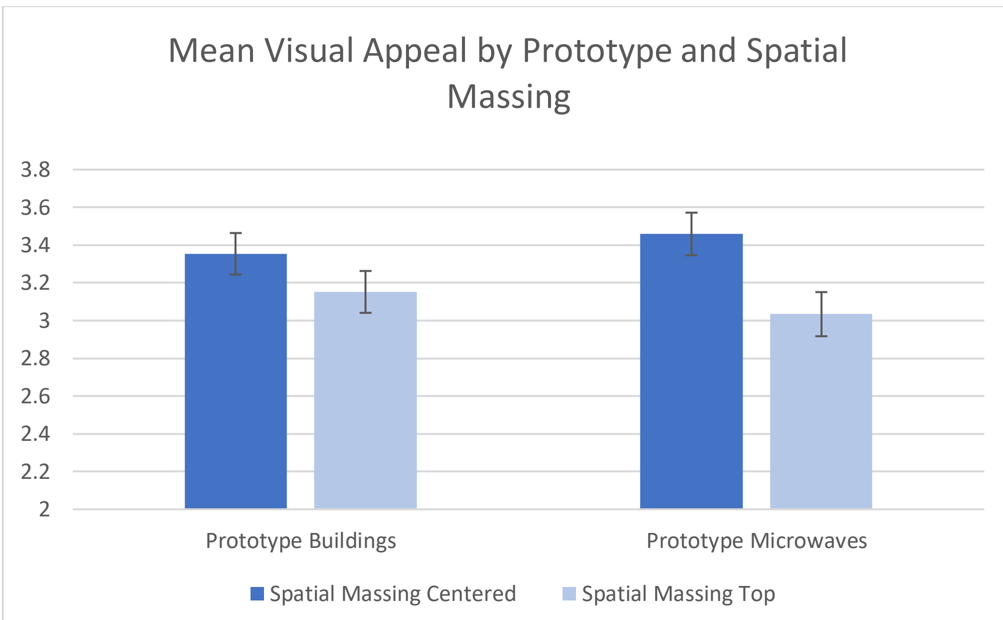


Figure 2.1 Mean Visual Appeal by Prototype and Spatial Massing

As with massing, curvature interacted reliably with prototype such that the effect of curvature was greater for stimuli that were created to look more like microwave control panels. Curvature had no significant impact on visual appeal in building prototypes ($t\{1,246\}=.18$; $p>.42$) but had a marginally significant impact on microwave prototype stimuli ($t\{1,246\}=-1.24$; $p=.09$) with curved microwave stimuli (M=3.56, SD=1.28) being preferred over angular stimuli (M=3.14, SD=1.48). Thus, with the microwave stimuli but not with the building stimuli, the aesthetic principle of curvature seems to hold, although the effect was weak.

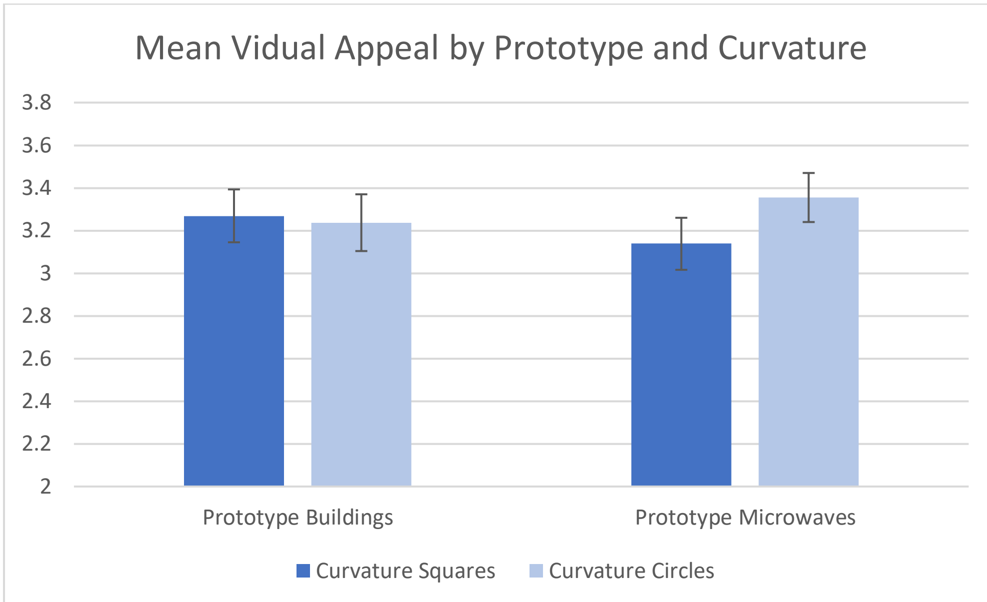


Figure 2.2 Mean Visual Appeal by Prototype and Curvature

It is crucial to point out that participants were not primed in this experiment as to what the intended use of the stimuli would be. By not priming the participants, we hoped to show that the appeal of the two design prototypes were similar. However, prototypicality did significantly interact with both spatial massing and curvature, showing that the impact of two important aesthetic dimensions was dependent of which prototype participants were rating.

Even without a prime, it is reasonable to infer that participants might have classified the objects based on their own mental prototypes for what are, after all, commonly encountered objects. From the open-ended question at the conclusion of the study (i.e., “What did the images you just saw remind you of, if anything?”), 53% of participants indicated that they thought that the stimuli reminded them of a television remote control. No participants indicated microwave control panel; however, remote controls share many design features with other types of controls, such as those for microwaves. If participants were classifying stimuli without prompting, and the intended microwave control panel stimuli were actually being perceived as remote controls, then a preference for curved elements might be expected. It is not uncommon for remote controls, be it television, DVD, or cable box, to utilize curved objects as buttons.

Figure 2.3 Cable box remote with curved buttons

Chapter 3: Experiment 2

Method

In the second experiment, a functional prime was presented to the participants before viewing the same stimuli used in Experiment 1. These primes were part of the task instructions and were simple mentions of the type of object the design illustration represents (i.e., building facade or microwave control panel). The purpose of the second experiment was to determine whether participants when asked to focus on the visual appeal of the stimuli would be influenced by the functional nature of the object when they made judgments of visual appeal.

Experimental Design. A mixed-factor experimental design was utilized for Experiment 2. Participants were randomly presented with one of two primes – either instructions explaining 1) that they will be judging the visual appeal of building facades, or 2) that they will be judging the visual appeal of microwave control panels. Both groups were presented with the entire set of sixteen stimuli described for Experiment 1. As with Experiment 1, ratings of visual appeal will be the primary dependent variable, although total time to complete the session will also be collected as a potential blocking factor for follow-up analyses. The design will be a 2 (instructional set) X 2 (prototype) X 2 (symmetry) X 2 (curvature) X 2 (spatial composition) factorial design. All factors are manipulated as repeated measures except for instructional set.

Participants. 122 participants were recruited via Mechanical Turk (MTurk) (http://www.mturk.com) and were self-selected into the study. The same inclusion criteria was implemented from Experiment 1.

Stimuli. The same stimuli from Experiment 1 (see Table 2.1) was used in Experiment 2.

Procedure. The procedure for Experiment 2 was identical to that of Experiment 1 save for the instructions presented to the participants. For participants randomly assigned to the microwave-primed condition the instructions read: “The following line drawings represent design ideas for a new microwave control panel. We are interested in how visually appealing each design is to you. Please move the slider to indicate how much you like each design. Be sure to consider only how appealing the drawing appears to you. We want your first impressions, so please make your judgments as quickly as possible.”

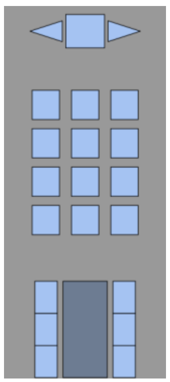
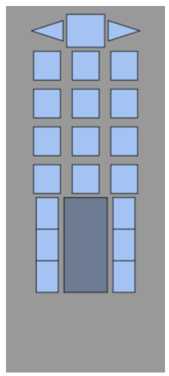
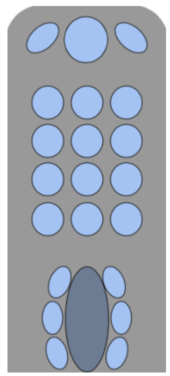
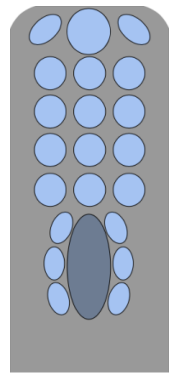
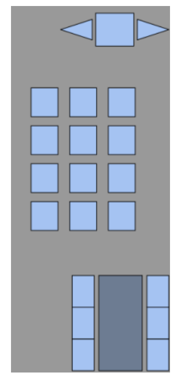
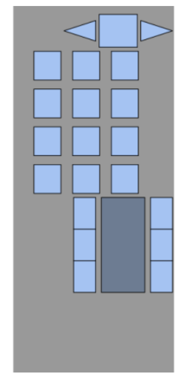
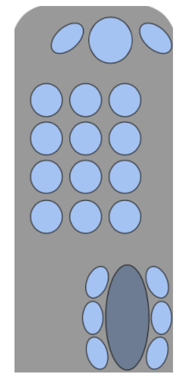
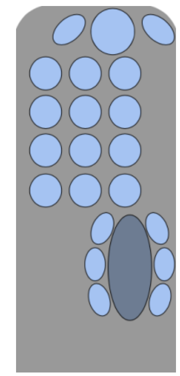
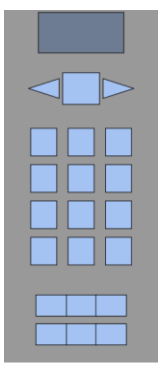
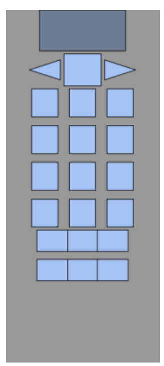
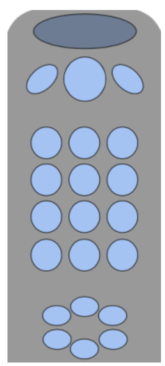
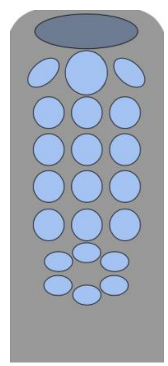
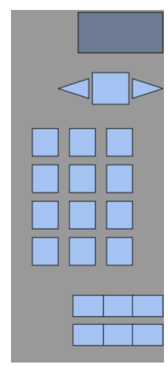
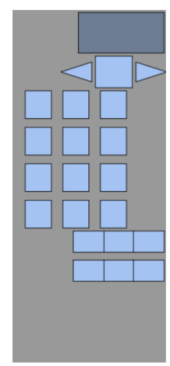
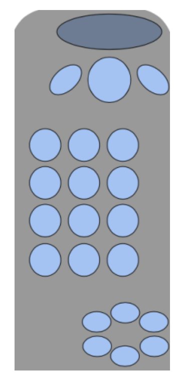
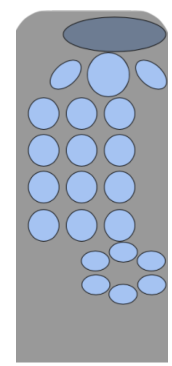
For participants assigned to the building facade condition, the prompt was the same as the microwave prime but with the first sentence replaced with: “The following line drawings represent design ideas for the front of a new multi-story building.”

Results

Experiment 2 followed the same procedure as Experiment 1 with one exception -- participants were randomly presented with one of two sets of instructions. The instructions informed the participants that they were to rate images for either microwave control panels or building facades. Before rating the stimuli, participants had to successfully complete a comprehension question that ensured that they knew the function of the stimuli they were about to see.

Data (i.e., ratings of appeal) were submitted to a 2 (symmetry) X 2 (massing) X 2 (curvature) X 2 (prototype) X 2 (prime) mixed-factor ANOVA, with prime treated as a between-subjects factor and symmetry, massing, curvature, and prototype as repeated measures. The purpose of the analysis was to determine if any of the aesthetic principles significantly predicted users' ratings of visual appeal and if the introduction of a functional prime moderated these effects. Data from 124 participants were utilized for the analysis. As inspection of Table 3.1 shows, there is a trend similar to that found in the previous experiment, with participants preferring symmetric, evenly distributed stimuli. The interpretation of the formal statistical analyses will describe the effects of each of the aesthetic principles, as well as the between-subjects prime, in turn.

Table 3.1 Descriptive statistics for stimuli in Experiment 2

Design Manipulations	Symmetrical, angles, centered	Symmetrical, angles, vertical bias	Symmetrical, curves, centered	Symmetrical, curves, vertical bias	Asymmetrical, angles, centered	Asymmetrical, angles, vertical bias	Asymmetrical, curves, centered	Asymmetrical, curves, vertical bias
Based on Building Façade Prototype								
Descriptive Statistics	M= 4.74 SD= 1.68	M= 3.83 SD= 1.89	M= 4.27 SD= 1.92	M= 3.52 SD= 2.05	M= 2.76 SD= 2.03	M= 3.826 SD= 1.89	M= 2.65 SD= 2.13	M= 1.95 SD= 1.85
Based on Microwave Control Panel Prototype								
Descriptive Statistics	M=4.57 SD= 1.84	M= 3.44 SD= 1.89	M= 4.32 SD= 1.98	M= 3.96 SD= 1.81	M= 2.43 SD= 1.90	M= 1.96 SD= 1.96	M= 2.26 SD= 1.96	M= 1.93 SD= 1.90

Prime. The introduction of a functional prime resulted in numerous significant interactions with aesthetic principles on visual appeal, thus rejecting the basic hypothesis that the effect of aesthetic principles is independent of the perceived function of the designed objects. First, as can be seen in Figure 3.1, prime reliably interacted with design prototype ($F\{1,121\}=10.00$*;* $p<.002$, $\eta^2=.076$). This interaction is driven by the congruence of the prime and design prototype, with participants generally preferring the stimuli that were more similar to the class of object with which they were primed. Post-hoc comparisons revealed, however, that the congruence effect was stronger for participants primed to expect buildings (building prime, $t\{1,112\}= 1.95$, $p<.05$; microwave prime, $t\{1,130\}=-.49$, $p>.3$).

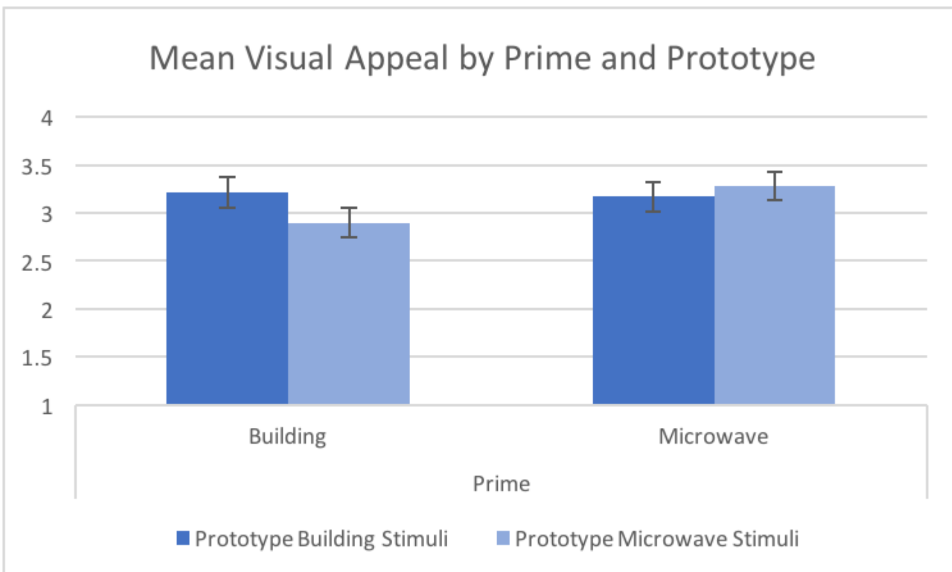


Figure 3.1 Mean Visual Appeal by Prime and Prototype

Prime also interacted with object curvature ($F\{1,121\}=12.29$*;* $p<.001$, $\eta^2=.092$), such that square objects were significantly preferred over curved ones for participants primed with buildings ($t\{1,112\}= 1.99$*;* $p<.03$) however, there was only a marginally significant difference for shape in microwave-primed participants ($t\{1,130\}= -1.39$*;*

p<.08). This finding is also consistent with predictions of the prototype principle because windows of buildings are typically square or rectangular and response keys on a variety of devices are often curved. In short, participants appear to prefer the stimuli based on the design prototype that was congruent with the mental prototype activated by the prime.

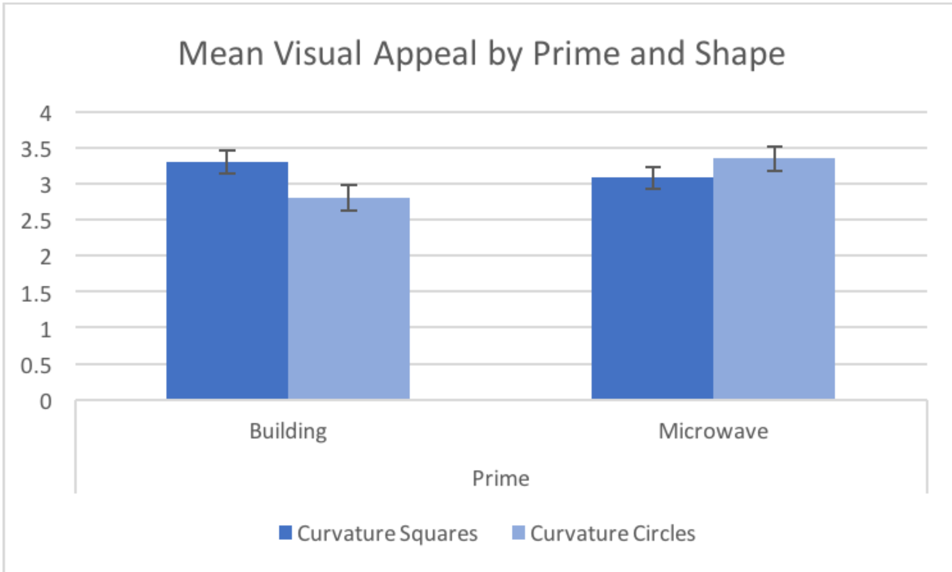


Figure 3.2 Mean Visual Appeal by Prime and Curvature

Lastly, there was a three-way interaction involving prime, prototype, and spatial massing ($F\{1,121\}=6.979$; $p<.009$, $\eta^2=.055$). As figure 3.3 shows, regardless of the specific combination of prime and design prototype, participants preferred centered rather than top heavy designs. However, the advantage for centered stimuli seemed to be smaller in the case of microwave design prototypes primed as buildings.

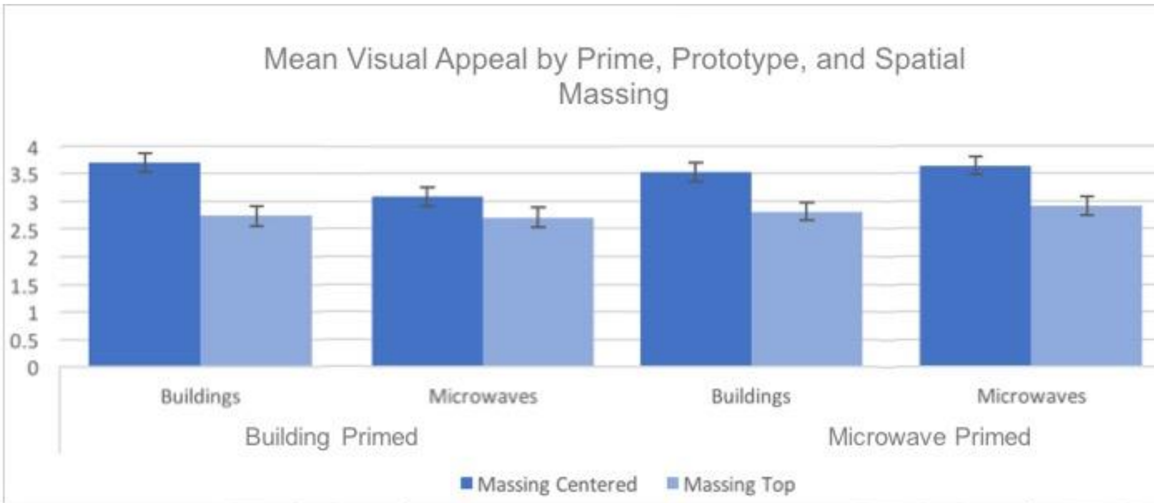


Figure 3.3 Mean Visual Appeal by Prime, Prototype, and Spatial Massing

Symmetry. As in Experiment 1, there was a large main effect for symmetry ($F\{1,121\}=181.64$; $p<.000$, $\eta^2=.6$), with symmetrical stimuli (M = 4.079, SD= 1.224) being strongly preferred over asymmetrical stimuli (M = 2.216, SD= 1.512). Additionally, symmetry reliably interacted with prototype and curvature ($F\{1,121\}=6.965$; $p<.009$, $\eta^2=.054$). As shown in Figure 3.4, there was a preference for symmetry regardless of the combination of curvature and design prototype. However, the strength of the symmetry effect varied by prototype-curvature combination, from greatest effect to least: angular building prototypes ($t\{1,243\} = 4.02$; $p<.000$), curved building prototypes ($t\{1,243\} = 3.98$; $p<.000$), curved microwave prototypes ($t\{1,243\} = 4.00$; $p<.000$), and angular microwave prototypes ($t\{1,243\} = 2.15$; $p<.01$).

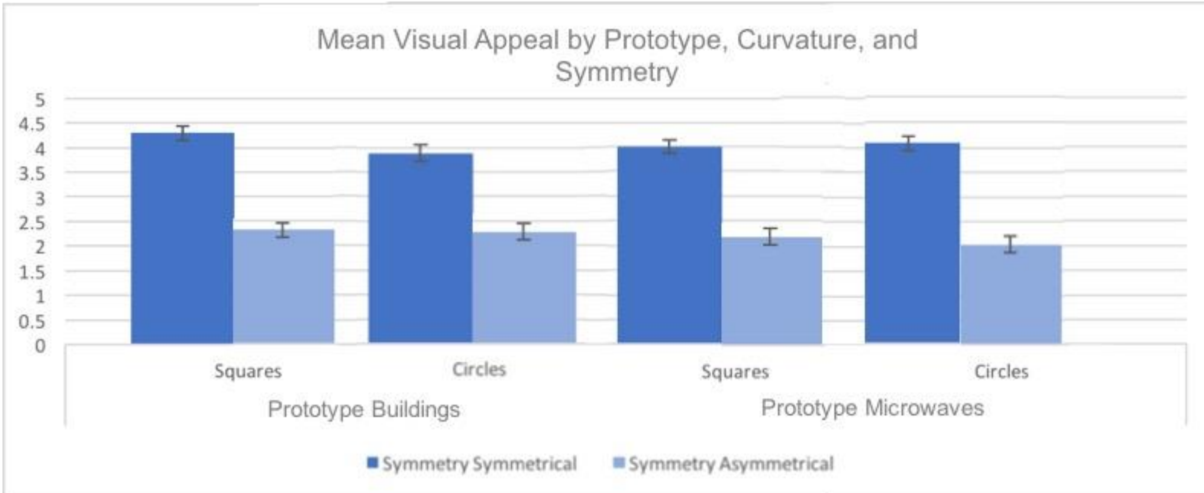


Figure 3.4 Mean Visual Appeal by Symmetry, Prototype, and Shape

Curvature. As with Experiment 1, the manipulation of curvature did not produce a significant main effect on users' ratings of visual appeal ($F\{1,121\}=1.207$; $p>.27$). Curved stimuli received a mean rating of 3.101 (SD=1.368) and angled stimuli received a mean rating of 3.117 (SD=1.368). Curvature did significantly interact with massing however which will be discussed below.

Spatial Massing. As with Experiment 1, spatial massing produced a large main effect ($F\{1,121\}=78.01$; $p<.000$, $\eta^2=.392$) with evenly distributed stimuli being rated as more visually appealing (M = 3.495, SD= 1.189) than stimuli with objects massed near the top of the frame (M = 2.684, SD= 1.252). Additionally, massing significantly interacted with object curvature ($F\{1,121\}=9.87$; $p<.002$, $\eta^2=.075$) such that the massing effect was larger for the angular stimuli ($t\{1,244\} = 2,13$; $p<.03$) than for curved stimuli ($t\{1,244\} = 1.98$; $p<.04$).

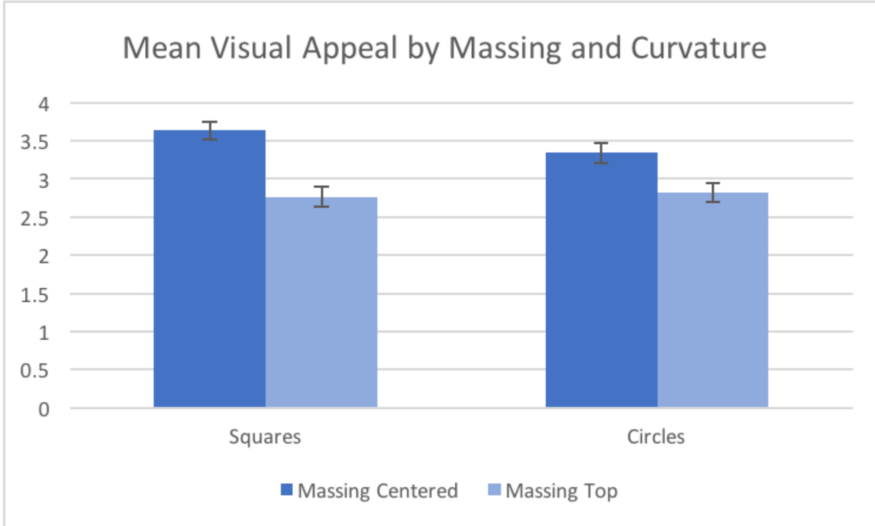


Figure 3.5 Mean Visual Appeal by Spatial Massing and Curvature

Prototypicality. As in Experiment 1, there was no significant main effect for design prototype (F{1,121}=2.361*; p*>.10). As described earlier, however, prototypicality did interact with all of the other aesthetic factors except curvature. The lack of a reliable interaction between prototype and curvature is a departure from the findings of Experiment 1.

Comparison of Experiments 1 and 2

Table 3.2 compares the findings of Experiments 1 and 2. The second experiment successfully built upon the results of Experiment 1 in two meaningful ways. First, the effects of massing and symmetry were replicated both in strength and direction. Second, the main effects of curvature and prototype were both non-significant in both experiment. Manipulations of symmetry and spatial massing, but not curvature and prototype, resulted in large differences in ratings of visual appeal and thus lend strong support for the aesthetic principles of symmetry and visual balance (massing).

Additionally, Table 3.2 also lists the interactions among the different principles in the two experiments. Of the two significant interactions in Experiment 1, only the interaction of prototype and spatial massing carried over to Experiment 2. The interaction of prototype and curvature not replicating in Experiment 2 could be, in part, due to participants automatically classifying the stimuli in Experiment 1 as remote controls, while in Experiment2 the classification was determined by the prime. It should be noted, in addition, that the interaction in Experiment 2 was also marginally significant (F{1,121}=4.731*;* p=.091, η^2=.054) trending in the direction of Experiment 1's results.

Explicit priming (Experiment 2) also yielded interactions that were not found in the initial experiment. The interaction of prototype, curvature, and symmetry was significant in Experiment 2 but not in Experiment 1. The strength of the symmetry effect might have been influenced by the "fit" of the prime and prototype in this experiment. Additionally, curvature and spatial massing interacted significantly in Experiment 2 but not Experiment 1. This effect may be due to a confound in the design of the square and round stimuli such that the square designs could be more compactly represented at the top of the frame, thus increasing the massing effect. However, this explanation for the interaction does not explain why it was not present in the first experiment.

The second meaningful observation comes from Experiment 2, with the demonstration that by providing a functional prime, differences in the predictions of the various aesthetic principles could be observed. For example, the manipulation of object curvature on its own did not create a difference in participant's ratings of visual appeal. However, when participants were primed for microwaves, they favored curvature. When they were primed for buildings, they found angular designs more appealing. The curvature effect and the interaction between design prototype and prime jointly indicate the importance of familiarity in judgments of aesthetic appeal.

Table 3.2 List of main effects and interactions in Experiments 1 and 2.

Manipulation	Experiment 1 effect size (η^2)	Experiment 2 effect size (η^2)
Prime	N/A	.005
Prototype	.000	.019
Symmetry	.609*	.6*
Curvature	.006	.01
Spatial Massing	.227*	.392*
Prototype X Spatial Massing	.042*	.049*
Prototype X Curvature	.053*	.023
Prototype X Symmetry	.000	.015
Symmetry X Curvature	.018	.002
Symmetry X Spatial Massing	.000	.022
Curvature X Spatial Massing	.003	.075*
Prototype X Spatial Massing X Curvature	.007	.014
Prototype X Spatial Massing X Symmetry	.018	.002
Prototype X Curvature X Symmetry	.015	.054*
Spatial Massing X Curvature X Symmetry	.026	.015
Prototype X Massing X Curvature X Symmetry	.023	.013
Prototype X Prime	--	.076*
Symmetry X Prime	--	.000
Curvature X Prime	--	.092*
Spatial Massing X Prime	--	.001
Prototype X Spatial Massing X Prime	--	.055*
Prototype X Curvature X Prime	--	.001
Prototype X Symmetry X Prime	--	.005
Symmetry X Curvature X Prime	--	.015
Symmetry X Spatial Massing X Prime	--	.004
Curvature X Spatial Massing X Prime	--	.016
Prototype X Spatial Massing X Curvature X Prime	--	.003
Prototype X Spatial Massing X Symmetry X Prime	--	.008
Prototype X Curvature X Symmetry X Prime	--	.007
Spatial Massing X Curvature X Symmetry X Prime	--	.001
Prototype X Massing X Curvature X Symmetry X Prime	--	.024

*Note: * denotes significance*

Chapter 4: General Discussion

The impetus for this study was to investigate the application of aesthetic principles to objects with which we interact, specifically looking at the impact of the functional class of the objects on visual appeal. The study of aesthetics in this context is important because much of the scientific literature on aesthetic judgments has focused on natural objects (e.g., faces) or else simple geometric forms that are divorced from a specific use (e.g.,(Jacobsen & Höfel, 2002; Jones et al., 2001). A primary finding was that all four aesthetic principles that drove the creation of our stimuli predicted aesthetic judgments under at least some circumstances. Some principles were stronger than others (e.g, the dominance of symmetry), and some were more likely to be contingent on the perceived function of the stimulus (e.g., curvature).

The manipulation of functional primes was seen not only as a way to study the prototype principle, but as a novel way of exploring the "What is Beautiful is Usable" relationship debated in the human factors and usability literature. That is, we were able to logically manipulate usability without changing any physical aspects of the stimuli. The current study attempted to operationalize manipulations of aesthetic principles to determine if users' appraisals were consistent across different functional domains to test the null hypothesis that aesthetic principles can be universally applied. These data suggest that perceived usability can drive perception of beauty in stimuli of the type studied in human factors.

Certain aesthetic principles were found to be very impactful on users' ratings of visual appeal. Manipulations of symmetry and spatial massing had strong effects on visual appeal regardless of the prime, with users strongly preferring symmetrical and evenly spaced (i.e., massed) stimuli. It should be noted that the massing effect was slightly smaller in a subset of the stimuli, but as we discuss in the limitations section below, this was likely due to an inadvertent confounding of amount of white space and massing in a subset of the stimuli. These two principles -- massing and symmetry -- could be considered global, configural principles that are dependent on the spatial relationship among parts of the overall object (e.g., elements representing doors, buttons) rather than on the presence of specific features (e.g., curvature). The impact of these two principles did not appear to be disrupted by changes in perceived function or use case. This finding is also in line with Lavie and Tractinsky (2004) focus on “classical aesthetics” in the usability literature, which focuses on principles such as symmetry, order and clarity, that have been used historically to define beauty and appears to be cross-cultural (Kruft, 1994).

Unlike the principles of symmetry and balanced composition, curvature's contribution to visual appeal was more circumscribed. The interaction of prime and curvature offers a clear example of how functionality can influence aesthetic perceptions. Here, participants who were primed for buildings rated stimuli with angular objects as significantly more visually appealing than stimuli with curved edges, and the opposite trend was found for those participants primed for microwaves. Even though there was no main effect for curvature in either experiment, the introduction of a functional prime revealed a preference for particular shapes that were consistent with the mental prototypes activated by the primes (e.g., rectilinear shapes for buildings and rounded edges and parts for microwaves). The interaction of design prototype and prime also gives credence to the prototype principle of aesthetics (Martindale, Moore, & West, 1988). For example, people should prefer stimuli with a relatively large and vertically oriented object near the base when they believed they were viewing a building because a prototypical building has a door near the ground. They should prefer stimuli with a large horizontally-oriented object near the top when they believed they were viewing a microwave control panel because most microwaves have a display at the top.

Limitations and Future Directions

While the results of the study shed light on the relationship between function and aesthetics, and hence between usability and aesthetics, several limitations should be noted. First, aesthetic principles were implemented in a binary fashion rather than in a more continuous one. For example, in manipulating spatial massing, objects within the frame were either evenly distributed or massed at the top of the frame. Considering the strength of the massing effect on participants' ratings of visual appeal, less extreme manipulations could be utilized to determine boundary conditions for the effectiveness of this principle. In fact, one inadvertent limitation in the consistency of the massing manipulation revealed that the magnitude of the manipulation mattered. The angular stimuli could be offset to the top of the frame more compactly than could the curved stimuli, resulting in a bigger massing effect for the angular stimuli (see shape X massing interaction in Exp. 2, for example).

As with spatial massing, the aesthetic principle of symmetry was manipulated in only one way for the present study. Symmetry was manipulated by offsetting some rows of objects to the right of the vertical axis. The effect size of this manipulation was very large, which is consistent with prior research that has demonstrated that symmetry around the vertical access is more salient than symmetry around the horizontal or oblique axes

(Fisher & Fracasso, 1987; Mach, 1959; Palmer & Hemenway, 1978; Rock & Leaman, 1963).

The prototype objects users experienced, buildings and microwave panels, are nearly always experienced in a symmetrically vertical orientation. In other words, the prototypes for these objects are composed of symmetrical, vertical layouts and as such, participants may be even more sensitive to violations of this aesthetic principle than they normally would be with more basic stimuli. Future research into symmetry as an aesthetic principle for product design could implement more manipulations of symmetry both by type (horizontal, diagonal, and/or rotational) and could explore the impact of symmetry in object classes that tend to use symmetry around axes other than vertical. It would be particularly interesting to compare symmetry effects in designs that are familiar as asymmetrical forms, such as left-justified text.

In general, by manipulating symmetry on a more granular basis, we could learn about the possible relationship of classical and expressive aesthetics principles. Expressive principles, unlike classical principles, value novelty and the intentional violation of classical aesthetic principles. For example, it could be reasonable to assume that slight violations to symmetry (e.g., an offset key in a typewriter) would be less tolerable than more deliberate violations (e.g., a sculpture) of this classical aesthetic principle. In other words, can a violation of a classical aesthetic principle lead to appeal through expressive aesthetics if the asymmetry is large enough to be considered intentional on the part of the designer?

Implications for Design

With the results of the current study, it is important to reconsider the "what is beautiful is usable" arguments. Like other psychological theories, the "what is beautiful is usable" hypothesis has been conceptualized in "weak" and "strong" forms. Kurosu and Kashimura (1995)'s initial research and findings exemplify the "weak" form where the product in question seems to be more usable to people if it appears more beautiful to them. "Strong" forms of this hypothesis state that objects that are objectively lower in usability can be made to be more usable if they are perceived by users to be more beautiful (Ben-Bassat et al., 2006; Sonderegger & Sauer, 2010). In other words, "weak" posits that perceptions of beauty affect perceptions of usability; "strong" posits that perceptions of beauty can affect actual performance.

The data from the current study is only applicable to the weaker form of the hypothesis, as users did not actually interact with the stimuli and thus no data on performance could be collected. It does however, provide evidence that when perceived usability is manipulated (without changing the visual properties of the stimulus in any way), aesthetic judgements do change. In the present case, a stimulus seen as something one moves into and through (i.e., a building) may appear more appealing than if it is seen as something that one manipulates to achieve a specific goal (i.e., a control panel).

In addition, the impact of the curvature principle (but not spatial massing or symmetry) was found to be restricted to situations in which participants believed they were viewing a microwave control panel. This relationship may be another manifestation of prototypicality or familiarity. It could also be due, however, to our rapid perception of affordances (something that may appear pressable may be specific to hand tools or touch technologies) (Norman, 1999).

The current results are interesting not only because they shed new light on the "what is beautiful is usable" debate, but also because they can have immediate implications for product design. Consider an interaction designer working on a new interface for a mobile phone application. With the knowledge of the present results, this designer might prioritize aesthetic principles like symmetry and spatial massing above other design intents. Furthermore, a common point of contention between usability designers and industrial and interaction designers can involve the tendency of the latter to favor expressive aesthetics, thus driving for more novelty. The usability researcher who considers the importance of prototype theory may have a new way of persuading the colleague to favor familiarity of design. Not only will familiarity favor usability, but the usability specialist can assure the designer that people see familiar designs are more attractive.

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Curriculum Vitae

Travis Miller Kent

Education
University of Central Florida:
-B.S., Psychology, December 2011, Honors

University of Kentucky:
-M.S., Experimental Psychology, December 2017 (expected)
-Human-Technology Interaction Certificate, December 2017 (expected)

Professional Experience:
Internships
2017 (summer) User Experience Intern John Deere & Company – Moline Technology and Innovation Center
Manager: Joshua Hoffman

2015 (Jan-Dec) User Experience Research Assistant Google [x]
Manager: Dhvani Patel, Ph.D.

Research Assistant
2013- present University of Kentucky Center for Visualization and Virtual Environments
Adviser: C. Melody Carswell Ph.D.

Teaching Assistant
2014 (spring) Application of Statistics in Psychology (PSY 216). University of Kentucky. Professor: Hui Chu, Ph.D.
2016 (spring) Introduction to Psychology (PSY 100). Professor: Rachel Farr, Ph.D.
2016 (summer) Learning and Cognition (PSY 311). Professor: Andrew Hawkey, Ph.D.
2016 – present Cognitive Processes (PSY 427) Professors: Andrea Freidrich, Ph.D., Johnathan Golding, Ph.D., Larry Gottlob, Ph.D.

Peer-Reviewed Publications
Kent, T. M., Carswell, C. M., Lee, M., & Sublette, M. A. (2017, September). Do Aesthetic Design Principles Predict Visual Appeal of a Simple Control Panel? In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 61, No. 1, pp. 1414-1418). Sage CA: Los Angeles, CA: SAGE Publications.

Popham, J., Lee, M., Sublette, M., Kent, T., & Carswell, C. M. (2016, September). Flashy or Functional: The Impact of Graphical Content on the Effectiveness of Résumés. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 60, No. 1, pp. 1329-1333). Sage CA: Los Angeles, CA: SAGE Publications.

Kent, T. M., Fu, B., Walls, B. D., Seidelman, W., Sublette, M. A., Lee, M., ... & Yang, R. (2016, September). Does an Abstract Weld Pool Visualization Help Novice Welders Assess the Performance of a Weldbot? In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 60, No. 1, pp. 1309-1313). Sage CA: Los Angeles, CA: SAGE Publications.

Sublette, M. A., Carswell, C. M., Lee, M., & Kent, T. (2016, September). Towards a Taxonomy for Classifying Intuitive Usability Prediction Strategies in Non-Experts. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 60, No. 1, pp. 1264-1268). Sage CA: Los Angeles, CA: SAGE Publications.

Fu, B., Seidelman, W., Liu, Y., Kent, T., Carswell, M., Zhang, Y., & Yang, R. (2014, July). Towards virtualized welding: Visualization and monitoring of remote welding. In *Multimedia and Expo (ICME), 2014 IEEE International Conference on* (pp. 1-6). IEEE.

Seidelman, W., Lee, M., Kent, T. M., Carswell, C. M., Fu, B., & Yang, R. (2014, September). Development of a Hybrid Reality Display for Welders through Applied Cognitive Task Analysis. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 58, No. 1, pp. 1174-1178). Sage CA: Los Angeles, CA: SAGE Publications.

Seidelman, W., Lee, M., Carswell, C., Kent, T., Fu, B., & Yang, R. (2014, April). User centered design of a hybrid-reality display for weld monitoring. In *CHI'14 Extended Abstracts on Human Factors in Computing Systems* (pp. 2059-2064). ACM.

Sublette, M. A., Carswell, C. M., Seidelman, W., Lee, M., & Kent, T. (2014, September). Can Incongruencies Between Prospective and Retrospective Ease-of-Use Perceptions Affect Post-Use Satisfaction Ratings?. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 58, No. 1, pp. 1314-1317). Sage CA: Los Angeles, CA: SAGE Publications.

Kent, T. M., Marraffino, M. D., Najle, M. B., Sinatra, A. M., & Sims, V. K. (2012, September). Effects of input modality and expertise on workload and video game performance. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 56, No. 1, pp. 1069-1073). Sage CA: Los Angeles, CA: SAGE Publications.