Products with Biomimetic Shapes Convey Emotions More Effectively

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Abstract. Nowadays, a successful product should not only possess enhanced aesthetic quality and smart functionality, it should also satisfy consumers via the emotions they derive from using the product. Biomimetic designs are broadly used in product design to emphasize emotional interaction. Therefore, understanding the psychological effects of biomimetic products is becoming an important issue in the development of products with strong affective qualities. Adopting a cognitive-emotional approach, this study explored the emotions evoked in consumers by biomimetic products. This included an investigation of the following three hypotheses: (1) Consumers' emotions can be influenced by products with biomimetic features; (2) The emotions evoked in consumers by concrete biomimetic features (i.e., human contours, facial shapes and plant shapes) are greater than those evoked by less concrete features. The results indicated that consumers have different degrees of emotional responses to products exhibiting different levels of biomimicry. Furthermore, the results also showed that consumers had different degrees of emotional responses to different types of biomimetic products. Additional results are also discussed in the paper.

Keywords: Biomimicry · Product form · Product emotion

1 Introduction

1.1 Background

Biomimicry is defined as "the imitation of the models, systems, and elements of nature for the purpose of solving complex human problems" (http://en.wikipedia.org/wiki/Biomimetics). The term "biomimicry" comes from the Ancient Greek words "bios," meaning "life," and "mīmēsis," meaning "imitation." Biomimicry is commonly used in innovative technologies, having been applied in the development of various technologies to allow them to mimic the appearance, behavior or functional features of structures and materials found in nature (Janine, 1997). Nowadays, biomimicry is used in mechanical construction, morphology, materials science, green energy technology and other related fields (Kezhong and Zhihua, 2004). Environmental design specialists define biomimetic designs as biophilic, emphasizing the maintenance and restoration of natural elements in the built environment (Kellert et al. 2011). Biophilic designs have been reported to have a great impact on people's positive emotions and to increase people's well-being in daily life (Montana-Hoyos, 2010). Moreover, in the field of

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product design, designers have been inspired by using natural shapes/forms or animal features in product designs, and their inclusion has led to the enhancement of emotional reactions among users when they subsequently use these products.

In the consumer market, the Italian kitchenware manufacturer Alessi has used natural elements such as plants, figures and natural contours as design elements to develop or shape its products. For example, the company's "magic bunny" toothpick holder and "Anna G." corkscrew wine opener were inspired, respectively, by rabbit shapes and human contours, as well as the movements of both species, which were utilized as metaphors in the kitchenware designs. Accordingly, we assume that products which incorporate biomimetic features as metaphors can enhance consumers' emotions. Along the same lines, it is speculated that products with strong product semantics can encourage users to interact with them more frequently and thus evoke their emotions more effectively. This is one of the hypotheses that were tested in this study.

1.2 Product Forms and Emotional Design

In a competitive consumer market, it is difficult for function-based products to effectively satisfy consumers' demands and inner desires (Petersen et al. 2004). At present, consumers often require a product to not only possess smart functionality and provide ergonomic satisfaction, but also to provoke an emotional response when used. Furthermore, Marzano (2000) and Desmet et al. (2001) have stated that, in the development of a new product, the emotional value of the product is an important factor in determining the product's ultimate success in the market. Moreover, Creusen and Snelders (2002) indicated that even the appearance of a product can cause pleasurable emotions among the consumers who observe it. On a related point, Norman (2007), a well-known cognitive psychologist, has claimed that there are three different levels of emotions: (1) sensory instinctive (i.e., "visceral") emotions; (2) behavior (i.e., "behavioral") emotions; and (3) intension reflection (i.e., "reflective") emotions. In this study, we have tended to focus on the first level of product emotions, visual instinctive emotions, in which users' emotions are basically derived from observing product appearances. Based on the results of prior research, we assumed that biomimetic designs have the potential to evoke consumers' emotional responses to a great degree.

1.3 Biomimetic Forms and Emotional Design

As mentioned above, biomimicry consists of a method for mimicking formations, colors and behaviors from natural life (Janine, 1997) in order to improve the quality of our own lives. In this context, a biomimetic product is herein defined as a "product that mimics the appearances, behaviors, functions or features of natural subjects including plants, animals or humans." In additions, "anthropomorphic" is an agent to natural entities, animals, and objects which provide human beings intent, motive, purpose or mood (Waytz et al. 2010). Both biomimicry and anthropomorphic concepts were utilized in this research.

Related research on robotic facial features has demonstrated that human preferences with regard to such features are affected by differences in the anthropomorphic degree of the features (Mori et al. 2012). Relatedly, the uncanny valley theory proposed that following an initial rise in the acceptability of such features as they approach a human-like appearance, their acceptability will then suddenly drop when the resemblance to humans becomes too close (Mori, 1970; Mori et al. 2012; Piwek et al. 2014). As for product aesthetics, the level of complexity in the appearances of products will result in a similar sort of uncanny valley in terms of reactions. The resulting graph of such responses is commonly referred to as the "inverted U-shape" (Berlyne, 1970). According to such results, we formulated two hypotheses: (1) consumers' emotions are influenced by products with biomimetic features; (2) the emotions of consumers evoked by concrete biomimetic features (i.e., features mimicking those of plants, human contours, and humanoid faces) are greater than those evoked by less concrete features.

2 Methods

2.1 Participants and Procedure

62 participants (31 males and 31 females ranging in age from 20 to 30 years old) participated in the test. In the experiment, the participants were asked to tick boxes in a questionnaire after observing stimuli which appeared in a random order.

2.2 Stimuli

Items of kitchenware were selected as the stimuli in the experiment because of their frequent usage in our daily lives and also due to their broad use of biomimetic designs. According to previous research results, the stimuli tested were confined to anthropomorphic features and plant features. More specifically, three types of biomimetic images incorporating, respectively, plant features, human contours, or human facial features were created and used in the experiment. Each type of stimulus contained four levels of biomimetic images, with the levels ranging from very concrete to least concrete. Physical models of a total of 12 stimuli were created, and each was photographed individually. Those photos were edited into 8 × 6 cm size images that were displayed in grey scale (Table 1).

2.3 Assessment

Mehrabian and Russell's (1974) emotional assessment (i.e., pleasure and arousal) paradigm was adopted to examine the participants' emotions because it has been used broadly in previous emotion-related research. A Likert scale consisting of nine response values per item was used.

Table 1. Stimuli incorporating plant features, human contours, or human facial features

Degree of concrete level	Type of Biomimicry		
	Plants	Human contours	Humanoid Faces
L1 Very abstract			
L2 Abstract			
L3 Concrete			
L4 Very concrete			

2.4 Experimental Design

In this study, there were three independent variables consisting of the plant, human contour, and humanoid facial features, while the emotional responses (i.e., pleasure and arousal) of the participants served as a dependent variable (see Table 2).

Table 2. Summary of variables

Variable	Type	Value
Biomimetic features	Independent	12 cases (4 shapes of plants, 4 shapes of figures, 4 shapes of humanoid faces)
Emotional responses	Dependent	Degree of valence (1–9 points) Degree of arousal (1–9 points)

3 Results

In this study, we examined the emotional responses of consumers resulting from different levels of biomimicry. More specifically, biomimetic forms including forms with plant, human contour, and humanoid facial features were tested in terms of the emotional responses they elicited.

The statistical results showed that the emotional scale (i.e., valence and arousal) adopted in this study demonstrated internal consistency and reliability with a Cronbach's alpha = 0.910. Furthermore, an ANOVA analysis was conducted to examine the effects of the biomimetic plant, human contour and human facial features in the forms ranging from the very concrete to least concrete forms. The results showed that there were significant differences between the effects elicited by the plant, human contour and human facial features for each level of concreteness ($F(11,198.993) = 61.750$, alpha = 0.05, $p < 0.001$).

3.1 Emotions Evoked by Biomimetic Forms with Different Levels of Concreteness

We examined the emotional effects (i.e., valence and arousal) of three types of biomimicry (i.e. plant, human contour and human facial features). As shown in Fig. 1, the results indicated that there were significant differences between the four levels of plant stimuli (Valence, $F(3, 39.208) = 12.323$, $p < 0.001$; Arousal, $F(3, 21.575) = 6.903$, $p < 0.001$).

Similarly, as shown in Fig. 2, the results indicated that there were significant differences between the four levels of human contour stimuli (Valence, $F(3, 67.726) = 21.675$, $p < 0.001$; Arousal, $F(3, 50.048) = 18.518$, $p < 0.001$). Specifically, the more concrete the form with human contours, the greater the level of emotion that was evoked.

Moreover, as shown in Fig. 3, the results indicated that there are significant differences between the four levels of humanoid facial stimuli (Valence, $F(3, 86.339) = 26.831$, $p < 0.001$; Arousal, $F(3, 60.907) = 19.552$, $p < 0.001$). Specifically, the more concrete the form with human facial features, the greater the level of emotion was evoked. However, the results also showed that the means values of emotion elicited displayed a slight drop after stimulus L3. This will be discussed in the next section.

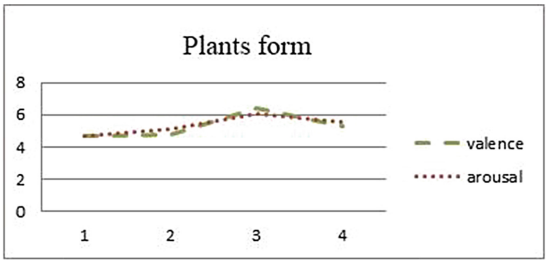

Fig. 1. The effects of stimuli with plant features on emotions

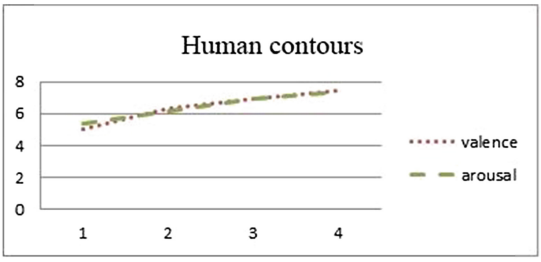

Fig. 2. The effects of stimuli with human contours on emotions

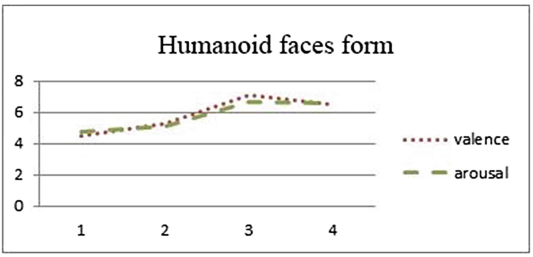

Fig. 3. The effects of stimuli with human facial features on emotions

3.2 Emotional Responses to Different Types of Biomimetic Forms

In this section, we further discuss the differences in participants' emotional responses to the different stimulus levels (i.e., L1, L2, L3, and L4). As shown in Table 3, the results indicated that there were no significant differences on the responses to the level 1, L2, level 3 stimuli in terms of both valence and arousal. Conversely, the results indicated that there was a significant difference on level 4 (Valence $F(2, 76.167) = 26.662$, $p < 0.001$; Arousal $F(2, 53.629) = 24.831$, $p < 0.001$). The results indicated that the participants' emotional responses followed the sequence of the responses to the human contour stimuli being greater than the responses to the human facial feature stimuli, which were in turn greater than the responses to the plant feature stimuli. This is discussed further in the next section.

Table 3. Emotional responses to different types of biomimetic forms

	L1	L2	L3	L4
Valence	F(2,5.167) = 1.331, p = 0.267 (PF = HF = HC)	F(2,41.699) = 13.321, p < 0.001 (HC > HF = PF)	F(2,8.860) = 3.130, p = 0.46 (PF = HF = HC)	F(2,76.167) = 26.662, p < 0.001 (HC > HF > PF)
Arousal	F(2,7.597) = 2.058, p = 0.131 (PF = HF = HC)	F(2,23.070) = 6.879, p = 0.001 (HC > HF = PF)	F(2,11.812) = 4.342, p = 0.14 (HC = HF > PF)	F(2,53.629) = 24.831, p < 0.001 (HC > HF > PF)

Note. PF: Plant forms, HF: Human facial forms, HC: Human contour forms;
L1: Least concrete, L2: less concrete, L3: concrete, L4: Most concrete;
(): Results from the multiple comparison tests ($\alpha = 0.05$)

4 Discussions

Mehrabian and Russell's (1974) emotional assessment paradigm was adopted to assess the participants' emotional responses in this study. We examined consumers' emotional responses to different types of biomimetic forms. For greater detail, we also examined consumers' emotional responses to biomimetic forms with different levels of concreteness. Regarding to L1, L2 and L3, the results indicated that products with more concrete biomimetic forms exhibited stronger potential to evoke consumers' emotions then those with less concrete biomimetic forms (see Figs. 1, 2 and 3). However, we found that the mean values of the responses to both plant and humanoid facial forms appeared to drop slightly in response to the level 3 stimuli (Figs. 1 and 3), a finding

which was in accordance with Berlyne's, (1970) inverted, U-shaped graph. Accordingly, this result further implied that the more concrete biomimetic forms are likely to have complex forms and to have a better chance to evoke emotions. In contrast to exhibiting an inverted U-shaped curve, the responses to the human contour stimuli (see Fig. 2) showed a positive linear relationship. It is possible that this was because even the level 4 stimulus was not concrete (real) enough in comparison to objects with a higher degree of human-likeness. It is suggested that this possibility be studied further in the future. In this case, it is believed that participants may prefer to observe more concrete forms and have greater emotional responses to such forms, but that the form should not appear to be too concrete (real), consistent with the Uncanny Valley theory of Mori (1970). It is believed that more concrete human-like forms will increase the degree of preference, before such form become too concrete. As shown in Table 3, the results indicated that the emotional responses to both the stimuli with human contours and the stimuli with human facial features were greater than the responses to the stimuli with plant features. This result implied that consumers' emotions are perhaps more strongly influenced by products with human features than by those with plant features. Current results were confirmed by the result of anthropomorphic robotic research from Cabibihan et al. (2006) and by Hekkert and Leder's (2008) study on products with human characteristics. In which, accordingly consumers had a preference towards a product with anthropomorphic features (Timpano and Shaw, 2013). In sum, it can be concluded from this research that products with biomimetic features, including plant features and human characteristics, should have a better chance to evoke consumers' emotions. The results also implied that more concrete forms have a greater chance to evoke emotions, at least until they reach a level of being too concrete (real). Overall, this research indicates that: (1) consumers showed different degrees of emotional responses to biomimetic forms with different levels of concreteness; (2) consumers showed different degrees of emotional responses to different types of biomimetic forms. Specifically, consumers showed greater emotional responses to products with anthropomorphic features. The results of this research can hopefully help designers to develop biomimetic products that elicit positive emotions.

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