Affective Responses of Interpolated Sketches

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Abstract. This study explored the expression differences between designer-interpolated shapes and computer-interpolated shapes under affective perceptual map. Multidimensional scaling (MDS) program was applied to construct product perceptual space as the basis to demonstrate the relationship among interpolation stimuli and affective adjectives. The designer-interpolated kettles have the tendency to design more fresh and modern images. Comparing the average distance between designer-interpolated kettles and midpoint of the source kettle, it is clear that the operations of interpolation image on the "simple-complex" axis are easier to create than the "contemporary-traditional" and "emotional-rational" axes. This study also proves the relationship between the computer-interpolated shapes and their affective responses to be nonlinear and non-uniform. The results showed under a condition of free design expression for the designer, the design purpose not only yields a finished product appearance but also represents the designer's will.

Keywords: Interpolation · Affective responses · Product shape · MDS

1 Introduction

Norman argued that the emotional side of design may be more critical to a product's success than its practical functions. Norman also considered this emotional aspect to be related to the complex brain structure at three emotional processing levels: visceral, behavioral and reflective [1]. Jordan observed that consumers expect a product to be not just a tool but a living object that expresses emotional image by its shape [2]. People could experience three different levels of affective responses toward a product – aesthetic experience, experience of meaning and emotional experience [3]. In addition to aesthetic pleasure, product forms provide a context for understanding all aspects of product design [4]. Helander and Tham indicated the most important task of affective research for human-factors design is to propose a satisfying survey method and theory. They also elucidated several significant issues in manipulating and researching affective design [5]. Manipulating affective images of product shapes thus becomes an increasingly important task for product designers.

Existing computer-aided tools only assist designers in drawing and modeling, and cannot offer much help in the challenge to develop products that convey specific affective meanings. There is a need for a computer-aided concept design system, with

S. Yamamoto (Ed.): HIMI 2015, Part I, LNCS 9172, pp. 55–66, 2015.
DOI: 10.1007/978-3-319-20612-7_6

which designers can rapidly explore a large number of product shapes and investigating their affective appeals. Many studies indicate that conventional media (such as design sketches) are simpler, intuitive and flexible than computers in concept-generation stages [6, 7, 8]. Although computer media could give immediately visualized feedback to the designer, these concrete images easily influence the designer and limit transformation in visual thinking and cognitive behavior [7]. Bilda and Demirkan [8] suggested a new invention-software package for computer-aided architectural conceptual design to fill the need for a natural cognitive process and stimulate interaction between mental imaging and digital-media simulation. Although CAD support is not currently appropriate in creative visual thinking, it is still a workable tool in automotive concept development [9]. In studies of the sketching behavior of designers, Lim et al. [10] indicated that integrating the advantages of paper drawings and CAD tools could provide a flexible sketching and modeling environment to help designers in the early stages of design. In exploring a new CAD system concept to represent and maintain vague geometric information of shapes in an early conceptual design stage, Lim, et al. [11] proposed morphing techniques as helpful for visualization, reuse and giving probability of shapes to support flexible conceptual design.

Among the many different ways of generating new shapes, interpolation is a technique that generates a series of gradually changing shapes from one shape to another. The morphing technique can generate highly realistic images to blend two objects. In the field of psychology, there has been much research on face perception where morphing techniques synthesized virtual faces for experimental studies [12–14].

Computer tools, such as Elastic Reality from Avid, can automatically generate a series of shapes from two given shapes (after specifying correspondences between them). Interpolating product shapes enables designers to quickly visualize varying shapes with gradually changing affective meanings. This technique may become a viable tool in a computer-aided concept design system.

Some proposals apply interpolation (or morphing) to automatically generate new designs. Chen and Parent proposed a "shape-averaging" method, where "averaged" wire-frame computer models create new shapes [15]. They suggested that shape averaging can predict the trend of a shape by averaging the different existing shapes, or extrapolating shapes to represent different views over time. Wang used shape interpolation to automatically create many in-between shapes in the design process for computer-aided styling [16]. Hsiao and Liu [17] applied three-dimensional morphing which automatically generates new product shapes based on desired affective-response specifications. Independently, Chen et al. proposed a set of visualization tools to explore affective product shapes by combining existing products that are successful in communicating certain affective meaning [18, 19]. These studies demonstrate the possibilities of applying the interpolation technique to realize and operate affective responses of product shapes.

Design examples from actual practice indicate that product designers sometimes derive new shapes by using interpolation techniques, particularly when specific styles or images need to be maintained. For instance, automobile designers from time to time apply interpolation techniques to bring in new styles while keeping a consistent brand or model image. Although the interpolation technique is employed by designers in practice, there have been few studies about exactly how designers interpolate between shapes. Do they operate directly on the overall shapes? Do they mix and match individual shape features? Do they operate strictly on the shapes? This study therefore analyzes sketches made while attempting to interpolate two product shapes, comparing these sketches to those generated automatically by computer software, to discover the similarities and differences. These investigations helped determine the requirements for a computer-aided concept design system that supports design thinking patterns.

2 Experiment Design

To investigate how designers interpolate shapes, designers were asked to sketch shapes that interpolate halfway between the two given product images. The two source products need to have very different characteristics to compare designer-interpolated shapes with the original shapes and uncover the interpolation method. To select very different source products, this study constructed a basic product perceptual space using a multidimensional scaling program, then selecting source products that lie at extremes of the perceptual space. Nine senior designers, each with at least five years' professional experience in product design, participated in the experiment. Each designer was expected to create his or her own interpretation of the interpolated shapes. On the other hand, the computer-generated interpolated shapes were free of designer's interpretations, allowing comparison of the designer-interpolated shapes to computer-interpolated shapes.

3 Stimuli Selection

A coffee kettle was the product for this research. A collection of sixty-four kettle images covered the range of variations in product shapes. Using these images, a survey elicited affective adjectives to describe these products. Twenty subjects (fifteen undergraduate students and five lecturers from Chang Gung University, Taiwan) participated in the survey. This yielded six hundred and forty-five affective adjectives for describing kettle shapes from voice recordings of the survey. After eliminating similar and unsuitable words, one hundred affective adjectives for kettles remained.

By applying our past study result (Hsiao et al. 2005), researchers used the twenty-one representative products as stimuli and ten adjective pairs to measure affective responses conducting a semantic differential survey to determine perceptions of the kettles (Fig. 1). A multidimensional scaling program (MDPREF) [20] was used to construct the perceptual map of the twenty-one kettles; a preference-mapping program (PREFMAP) [20] was also used to determine the vector locations corresponding to the adjective pairs. In this map, each point corresponds to a kettle and each vector corresponds to an adjective pair. As the stimuli for the experiment, this study selected three kettles A, B and C that lie towards the extremes of the map and far away from each other. The three kettles clearly exhibit very different characteristics, as required by the experiment.

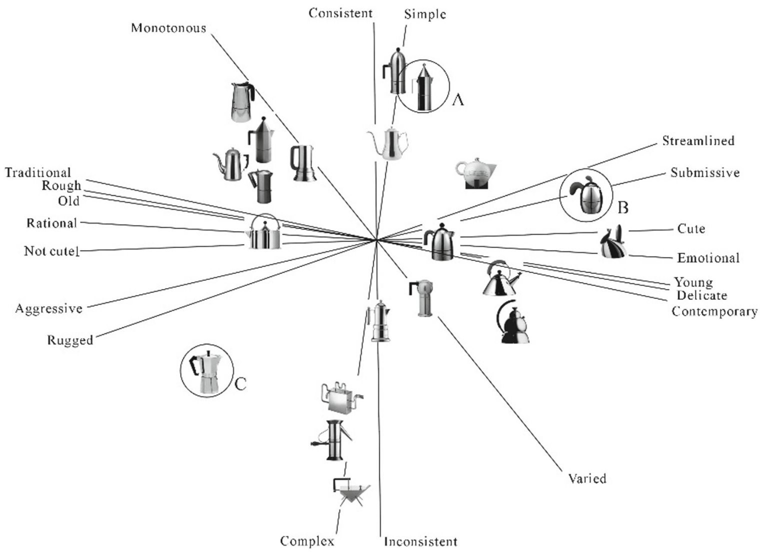

Fig. 1. Perceptual space of 21 kettles and 10 bipolar adjectives

4 Computer Interpolations

Because each designer may have his or her own interpretation of the interpolated shape between two given shapes, the computer-interpolated shape, free of any designer's interpretations, can serve as an analytical reference. Designer-interpolated shapes can be compared to computer-interpolated shapes to discover whether they share common features and in which aspects they are different. Researchers used a morphing software package, Elastic Reality from the AVID Company, to obtain the interpolated shapes between kettle pairs. The quality of computer interpolation depends on accurate definitions and correspondences of shape features between the two given kettles. This study defined the shape features of a kettle to be: (a) cap handle, (b) body handle, (c) cap, (d) opening, (e) upper half body, (f) bottom half body, (g) parting line of body and (h) light and shade. The last feature was needed because the kettles are made of metal which reflects light strongly. Figure 2 shows correspondence between two shape features (a. and b.) of kettles A and B for the morphing.

For pair-wise interpolation results of kettles A, B and C generated by the morphing software, in-between shapes are labeled A50/B50, to indicate respective weights (in percentages) of kettle A and B (Fig. 3). The image labeled A50/B50 corresponds to the "average" (interpolated) shape of A and B, and will be used as the comparison reference.

5 Designers' Interpolations

Nine senior designers, with at least five years of professional experience as product designers, participated in the experiment. One was from Phillip Design Center in Taiwan, two were from local design companies, two were lecturers teaching product

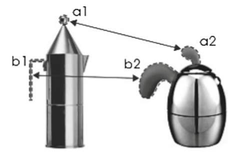

Fig. 2. Corresponding features between kettles A and B

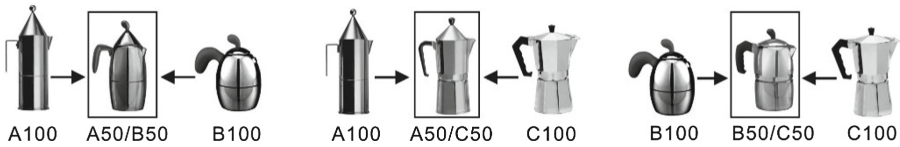

Fig. 3. Computer's interpolation between kettles A and B, A and C, B and C

design in the university, and the other four were in-house designers in computer companies. Each designer sketched the interpolated (50 % – 50 %) shape between one or two random pairs of kettles (A-B, A-C or B-C). The designer could freely express his or her interpretation in sketches, without any constraint on the number or the style of the sketches. Finally, from the numerous sketches, the designer chose a sketch that he or she felt best represented the interpolated shape between the two given kettles (Fig. 4, in arbitrary order). The designer-sketched interpolated shapes are more complex. Designers created many different interpolated shapes for the same pair of source products. Not all interpolated shapes are similar to the interpolated shapes computed by the morphing software. Some sketches emphasize particular elements from two source shapes; while, in some sketches, new elements different from those of the two source shapes were added to the interpolated shapes.

6 Perceptual Map of Sketches

To understand how people process the designers' interpolated shapes, an experiment interpreted the perceptual space of the source and interpolated kettles. Because the designer's sketches are drawn in very different styles that perhaps too abstract for subjects to envision as real products, these sketches formed the basis of three-dimensional digital models. Researchers used CAD software (Alias) to build the basic shapes and then used 3D Studio Max and VRay software packages to obtain highly realistic rendering of the sketched objects (Fig. 4).

In the same manner as described in Sect. 3, a multidimensional scaling program (MDPREF) was applied to construct the perceptual map and a preference-mapping program (PREFMAP) to determine the location of the vector corresponding to each adjective in the perceptual map using the twenty-one kettles (fifteen digital kettles, three source kettles and three halfway kettles with computer morphing) and ten

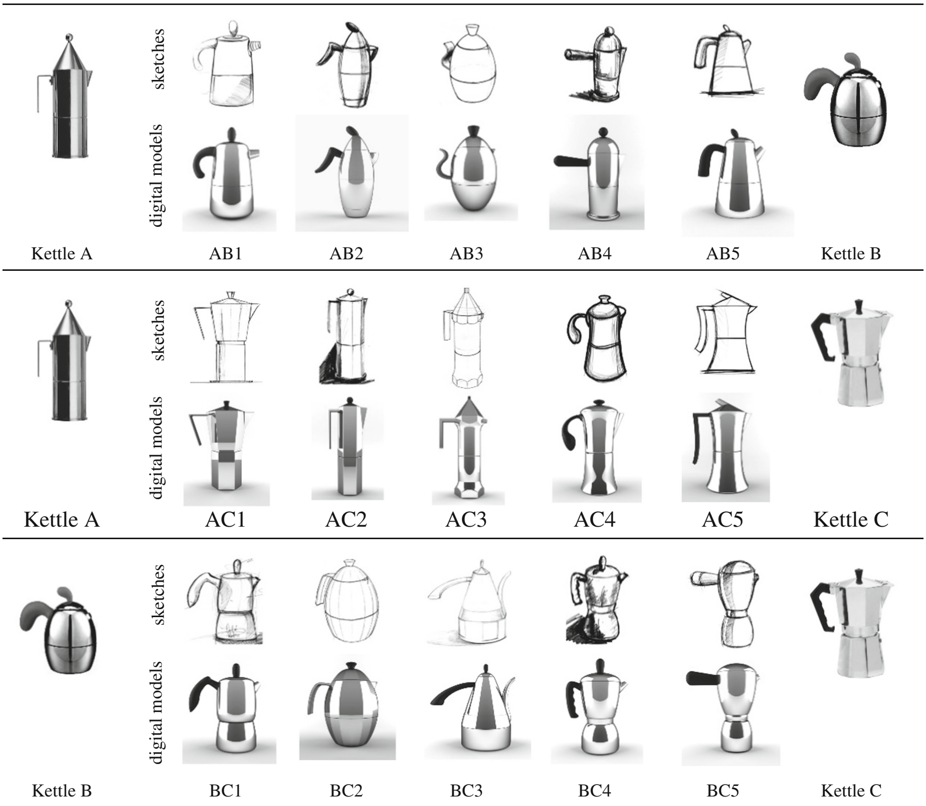

Fig. 4. Sketches and 3D digital models of designers' interpolations between two source kettles

representative adjectives. Forty subjects (twenty undergraduates and twenty post-graduates in Chang Gung University) participated in the experiment.

Figure 5 shows the perceptual space of the twenty-one kettles and the ten adjectives. Figures 6, 7 and 8 show the perceptual space between source kettles A-B, A-C and B-C respectively, which were isolated from Fig. 5. The distribution of designer-interpolated kettles from Figs. 5, 6, 7 and 8 shows that designers' inter-polations do not exactly lie halfway between source kettles in this experiment. But some sketch kettles, such as AB5 for source kettles A-B, AC1 for source kettles A-C and BC1 for source kettles B-C, can be very close to the targeted halfway shapes in the perceptual space. Most kettles cluster to the right side of perceptual space, which represents more contemporary, emotional and simple imagery. This indicates that designers provided the products with more fresh and modern images, even though they were supposed to express the new kettle image halfway between the two source kettle images. This phenomenon is in contrast to the distribution of computer-morphed kettles which tend to express more complex and inconsistent images.

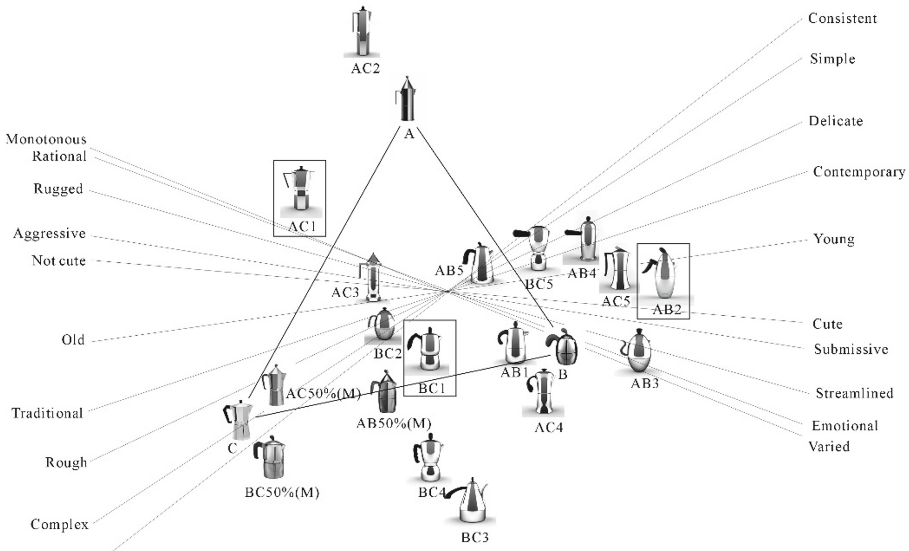

Fig. 5. Perceptual space of 21 kettles and 10 bipolar adjectives

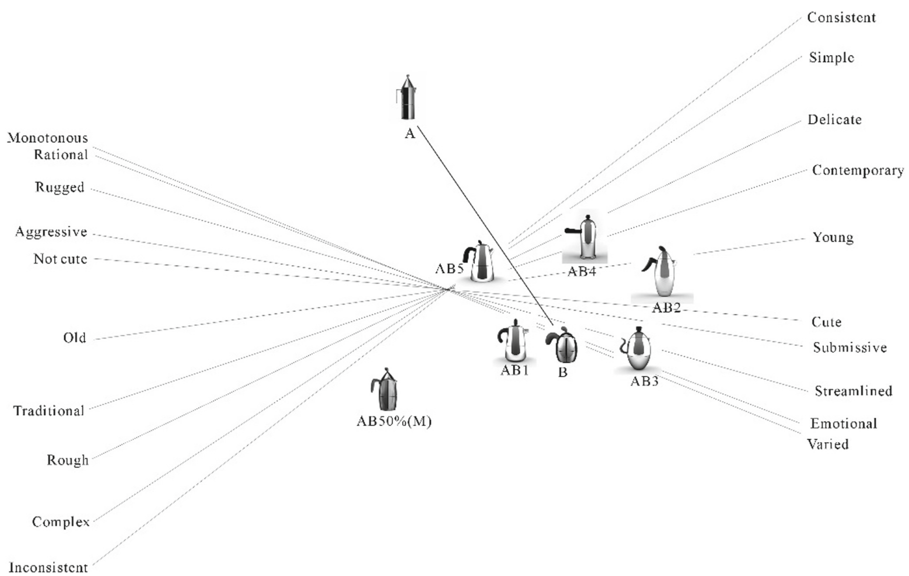

Fig. 6. Perceptual space of 5 designer-interpolated kettles and 1 computer-morphed kettle between source kettles A and B.

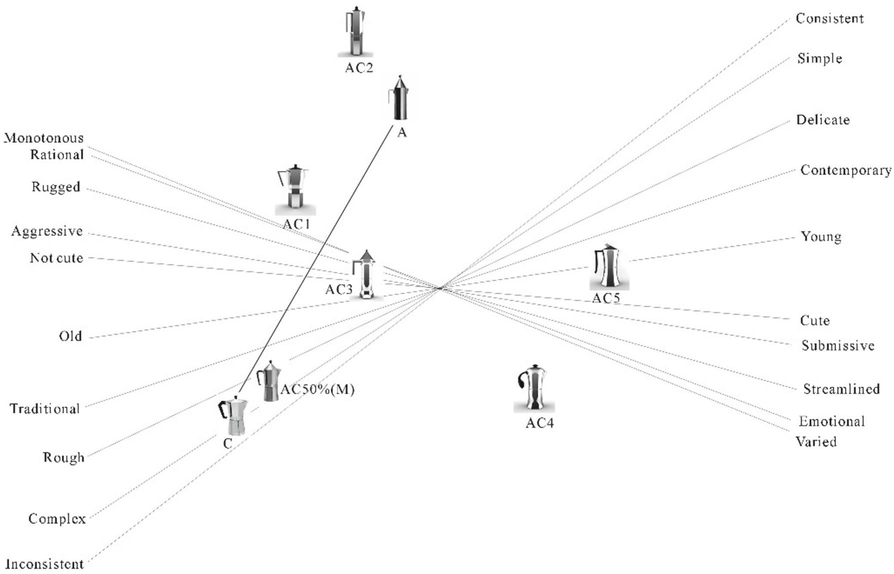

Fig. 7. Perceptual space of 5 designer-interpolated kettles and 1 computer-morphed kettle between source kettles A and C.

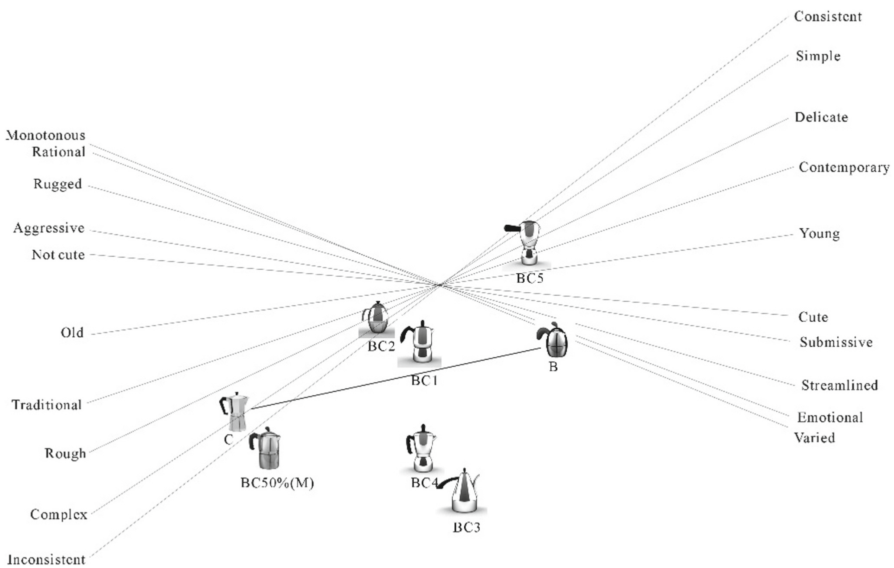

Fig. 8. Perceptual space of 5 designer interpolated kettles and 1 computer morphed kettle between source kettles B and C.

To examine the relationship between twenty-one different kettles and affective responses for each adjective, researchers vertically projected the points corresponding to the products to each vector of bipolar adjective and then calculated the *L-values* between the projections and the origin. Figure 9 shows an example of L-values for kettle B on the "simple-complex" axis. A large (resp. small) L-value indicates strong (resp. weak) of affective responses corresponding bipolar adjective. Positive (resp. negative) value indicates positive (resp. negative) effect on the corresponding adjective (e.g., contemporary, young).

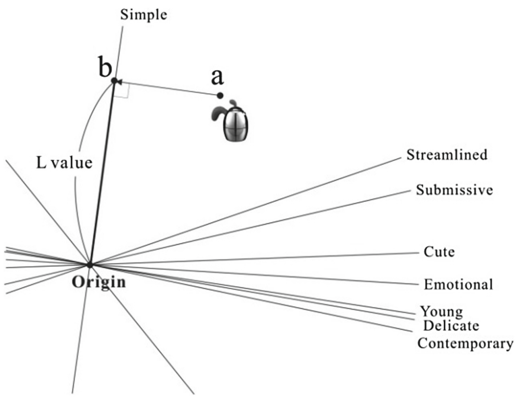

Fig. 9. L-value of kettle B on "simple-complex" axis

The L-value was calculated to further clarify the perceptions of the interpolated kettles in the perceptual space. The L-value of experimental kettles in three bipolar adjectives (Table 1): "contemporary-traditional", "emotional-rational" and "simple-complex" which were previously distilled as important fundamental dimensions of affective responses [21]. (1) The L-value of AB5, AC1 and BC1 are closest to the midpoint of source kettles A-B, A-C and B-C with respect to all three bipolar adjectives. Therefore, kettles AB5, AC1 and BC1 may most closely represent the halfway interpolation between the two given product images for the three bipolar adjectives. (2) The average L-distance of five designer-interpolated kettles is greater than the midpoint of source kettles for three bipolar adjectives. Thus, all designer-interpolated kettles have a more fresh and modern image. (3) Observing the distances between average (L-value) and the midpoint of the source kettles, researchers found that the shortest distance is in the "simple-complex" axis for all pairs source kettles: A-B, A-C and B-C. This result indicates that the operations of interpolation are easier to represent in "simple-complex" than in "contemporary-traditional" and "emotional-rational" axes.

7 Affective Responses of Interpolated Shapes

Figure 10 showed the Designer-interpolated shapes and computer-interpolated shapes between source kettles A-B, A-C and B-C. Previous study showed the relationship between the interpolation shapes created by computer and their affective

Table 1. L-values of experimental kettles in three bipolar adjectives

	A	**AB1**	**AB2**	**AB3**	**AB4**	**AB5**	**B**	Midpoint of source kettle A-B	Average distance of five sketch kettles	Distance between average and midpoint
Contemporary -traditional	−0.0083	**0.043**	0.2778	0.2538	0.1707	−0.0204	0.1564	0.074	0.14498	0.07098
Emotional -rational	−0.1727	0.1537	0.3075	0.2753	0.1949	**0.0186**	0.2187	0.023	0.19	0.167
Simple -complex	0.2343	0.0631	0.2691	0.0919	0.2834	**0.1266**	0.0971	0.1657	0.16682	**0.00112**
	A	**AC1**	**AC2**	**AC3**	**AC4**	**AC5**	**C**	Midpoint of A-C		
Contemporary -traditional	−0.0083	**−0.1693**	−0.0079	0.2035	0.1651	0.2797	−0.4054	-0.2069	0.09422	0.30112
Emotional -rational	−0.1727	−0.3107	−0.3053	**−0.1851**	0.2018	0.2013	−0.2558	−0.2143	−0.0796	0.1347
Simple -complex	0.2343	**−0.0301**	0.1489	−0.3827	0.0297	0.2119	−0.3868	−0.0763	−0.00446	**0.07184**
	B	**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**C**	Midpoint of B-C		
Contemporary -traditional	0.1564	**−0.1163**	−0.0884	−0.0318	−0.0666	0.1626	−0.4054	−0.1245	−0.0281	0.0964
Emotional -rational	0.2187	**0.0103**	−0.0792	0.1343	0.0686	0.1127	−0.2558	−0.0186	0.04934	0.06794
Simple -complex	0.0971	−0.0489	**−0.0927**	−0.2438	−0.2174	0.1613	−0.3868	−0.1448	−0.0883	**0.0565**

responses to be nonlinear and non-uniform [19]. This study also proves the phenomenon. The interpolation product shapes trends to show more traditional, old, inconsistent and complex. This probably caused by the image quality processed by morphing technique. Even if researchers move interpolation shapes to the right size (Contemporary, young, consistent and simple), their affective responses still not locate close to the midpoint between source kettles. The affective responses of interpolation shapes seem shifting to the side of complex shape. Taking A-B interpolation as example, the affective responses of interpolation shape (A50/B50) shifting to kettle B. Kettle A was created by straight line and showed concise style. Even though made a little adjustment to change the straight line into larger radian, the simple and concise style of straight line will be broken into different affective responses. AB5, sketched by designer, seems solve this problem. Appling trapezoid shape to maintain the straight line but flexible, and create more organic shapes on the handle to demonstrate curve image. The result shows both affective responses from Kettle A image (straight line) and Kettle B image (curve line). Therefore, the manipulation of affective responses on product shapes not only whole shape changing but also shape features effect. Designers' interpolating sketches showed diversified appearances and affective experiences than the morphing shapes by computer. Under a condition of free design expression for the designer, the design purpose not only yields a finished product appearance but also represents the designer's will. The design expression could include affective responses of product experiences as aesthetic experience, meaning and emotional experience [3]. That could explain why designers demonstrate diverse product appearances and affective experiences in a restricted design condition.

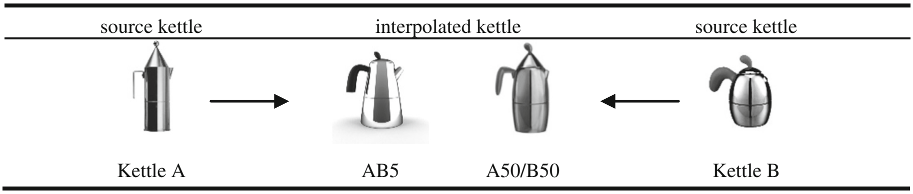

Fig. 10. Designer-interpolated shapes and computer-interpolated shapes between source kettles

8 Conclusions

This study explored the expression differences between designer-interpolated shapes and computer-interpolated shapes under affective perceptual map. By computing the perceptual map using realistic renderings of designer-interpolated kettles, computer-interpolated kettles and source kettles, three designer-interpolated kettles (AB5, AC1 and BC1) could most closely represent the halfway interpolation between the two given product images (source kettles A-B, A-C and B-C) for the three bipolar adjectives. The designer-interpolated kettles is also apparent that designers have the tendency to design more fresh and modern images, despite the request to express the new kettle halfway between two source kettle images. Comparing the average distance between designer-interpolated kettles and midpoint of the source kettle, it is clear that the operations of interpolation image on the “simple-complex” axis are easier to create than the “contemporary-traditional” and “emotional-rational” axes.

This study also proves the relationship between the computer-interpolated shapes and their affective responses to be nonlinear and non-uniform. The results showed computer-interpolated shapes could keep precisely blending contour shape but not for affective responses between two assigned product shapes. Comparing the computer-morphing method with the designer’s interpolation, design sketches are much more flexible and interpolations performed on more than the shapes. The results suggest that a computer-aided concept design system based on the interpolation technique should include functions for computing morphing of overall shapes, and functions for combining shape features from different source shapes to create new shapes. The interpolation of concepts is difficult to implement in computers, at least with current technology.

Acknowledgment. The authors thank the National Science Council of Taiwan supporting this research under grant number NSC- 92-2213-E-011-007 and MOST 103-2410-H-017-028-MY2. They would also like to express appreciation for all designers who participated in the experiment.

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