DESIGN BACKGROUND STUDENT PERCEPTION ON THE TEXTURE OF LIGHT METAL SURFACE TREATMENT

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ABSTRACT

Being lightweight, recyclable, highly moldable, and fast cooling, light metal materials are suitable for many types of processing and surface treatments. Advances in technology have further widened their range of applications, and the number of products using light metals (such as the cases of cell phones or tablet computers) has increased in the last few decades. This study uses aluminum alloy, the most typical application of light metals, as the material. The material was processed using the five most typical surface processing methods (i.e., hairline, sand blasting, polishing, anodizing, and turning), and the resulting textures were used as the contributing attributes to the mental images perceived by the users. Using Semantic Differential method, one hundred twenty subjects were asked to check on five categories of 15 pairs of adjectives that described the potential mental images. The final analyses focused on finding Factor analysis of the perceived characterizations of the texture by the subjects generated three factors. 1. The Activity factor consists of seven (7) pairs of opposing adjectives: Curved/Straight, Soft/Rigid, Natural/Artificial, Organic/Geometric, Dynamic/Static, Light/Heavy, Variable/Monotonous. 2. The Evaluation factor consists of six (6) pairs of opposing adjectives: Industrial/Artistic, Trendy /Traditional, High-value/Low value, Stable/Fluid, High quality/Low quality, Extravagant/Simple. 3. The Style factor consists of two (2) pairs of opposing adjectives: Decorative/Practical, Personalized/Popular. In the Activity factor, the Curved/Straight pair was ranked the highest. In the Evaluation factor, the Industrial/Artistic pair was ranked the highest. In the Style factor, the Decorative/Practical pair was ranked the highest. The subjects and the two groups of subjects with different educational backgrounds displayed did not show significant differences in their perceptions of the five aluminum alloy textures in terms of gender. In terms of their preferences, the five textures ranked polishing > hairline finishing > sandblasting > turning> anodizing.

Keywords: Light Metal Material, Aluminum alloy, Metal Image, SD Method, Factor Analysis

INTRODUCTION

Global trends in product weight reduction, energy conservation, and environmental recycling have led to the passing of legislation in Europe, the US, and Japan mandating that manufacturers be responsible for recycling their own products. Since the implementation of these laws between 2000 and 2005, many manufacturers have been using lightweight and recyclable materials in their products. As a result, the aluminum alloy industry has developed rapidly, thanks in part to its superior recyclability in comparison with plastics. Since 1995, magnesium alloy (lighter than aluminum alloy) and titanium alloy (applied in aeronautics, high-end products, and medical care) have been receiving increased attention. The properties of aluminum, magnesium, titanium, and their alloys have made them a new generation of major structural materials capable of contending with plastics. Light metal materials are also found in electronic products and new applications are constantly appearing, which has further increases demand. In 2012, the Industrial Development Bureau of the Ministry of Economic Affairs in Taiwan initiated the Development and Promotion Project of the Light-Metal Industry, promoting the use of aluminum, magnesium, and titanium in industries and technologies associated with energy, machinery, transport equipment, electronic products, and sustenance.

Data published by the World Bureau of Metal Statistics (WBMS) indicated that the total demand for primary aluminum reached 42.35 million tons in 2011. Innovative processing of raw metal materials into composite materials can improve the physical structure of metals and flaws, thereby enhancing the visual appearance. Furthermore, new developments in the metal materials industry have provided designers with a wider range of options in the design of products. The utilization of texture shaping techniques has become particularly popular and helped to enhance the design value of many products (Xu, 2012).

Light weight and compact design are basic requirements for next-generation products. In addition, consumers now attach considerable importance to the visual and tactile properties of the products they carry with them and the high-tech appearance of light weight metals means that they are increasingly employed in the design of technology products. Manufacturers are investing a considerable effort to develop processing techniques for these materials, including arced and curving surfaces and various textures. Some classic examples include Philippe Starck's Juicy Salif, Konstantin Grcic's Chair One Stacking, and ic! berlin eyewear (Fig. 1).

Juicy Salif | Chair One Stacking | ic! berlin eyewear

Figure 1. Juicy Salif, Chair One Stacking, and ic! berlin eyewear

LITERATURE REVIEW

Light Metal Material

The Metal Industries Research and Development Center of Taiwan defines light metal material as a metal with an atomic mass and a density of less than 4.5 g/cm3(Lin, 2012). The Japan Institute of Light Metals simply defines light metal material as a metal with a density of less than 4.5 g/cm3. The elements used in these alloys include aluminum (specific gravity: approximately 2.7), magnesium (specific gravity: approximately 1.8), and titanium (specific gravity: approximately 4.5). The advantages of light metal materials include light weight, fast heat dissipation, good corrosion and oxidation resistance. They also provide excellent moldability, high strength, good electrical conductivity, good thermal conduction, easy surface treatment, good workability, and are noty susceptible to embrittlement at ultralow temperatures (Liu, 2003). They also provide good heat resistance, no toxicity, eco-friendliness, and high recyclability.

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Surface Treatment Techniques for Light Metal Materials

In the following, we introduce the most common surface treatments for light metal materials, such as aluminum (Lai, 1996).

Hairline Finishing

Hairline finishing, otherwise known as sand grinding, refers to the streaking of the metal surfaces to form hair-like lines. The result is a non-mirror-like metallic luster with strong decorative effects similar to silk or satin. Hairline finishing has been well-received in the market and subsequently found wide application (see Figs. 2 and 3).

Figure 2. Sony DSC T700 Camera

Figure 3. Texture of hairline finishing

Sandblasting

Sandblasting is the easiest and most economical method to remove sand, stains, or rust from the surfaces of cast metal pieces. It is also commonly used to tarnish and dull metal surfaces. Sandblasting provides surface roughness to enhance the adhesion of varnish and other coatings. Sandblasting with washed silica sand results in a light gray color whereas using angular sand creates a glittery brilliance like that of sandstone. Silica sand produced by crusher results in a light bluish gray, and black silicon carbide leads to dark gray (see Figs. 4 and 5).

Figure 4. Apple MacBook Air

Figure 5. Texture of sandblasting

Polishing

Polishing involves the use of physical machinery or chemicals to reduce the roughness of object surfaces. Polishing techniques are primarily used in precision machinery and the optical industry. Polished pieces have smooth surfaces with good reflectivity and this technique removes any tool marks or burrs produced during the metal cutting process (see Figs.6 and 7).

Figure 6. Italian-made Bialetti espresso pot

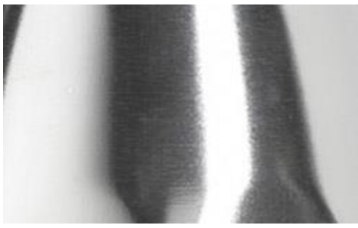

Figure 7. Texture of polishing

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Anodizing

Anodizing is a conversion coating technique. The ASTM defines conversion coating as a chemical or electrochemical process that enables metal surfaces to form a coating layer comprising said metal. Nearly all products with aluminum alloy exteriors are subjected to this surface treatment (see Figs. 8 and 9).

Figure 8. Apple iPhone 5 smartphone

Figure 9. Texture of anodizing

Turning

Turning involves the use of machine tools called lathes. The resulting texture on the metal surface is determined by the size of the work piece as well as the type, size, and speed of the turning tool (see Figs. 10 and 11).

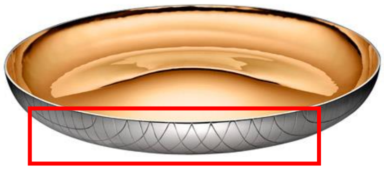

Figure 10. Karim Rashid's Christofle center piece

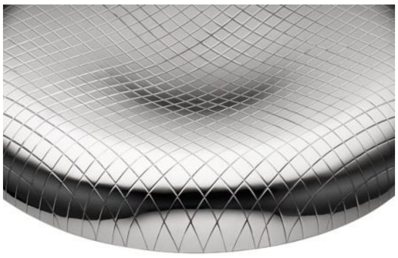

Figure 11. Texture produced by turning

Visual and Tactile Effects of Surface Treatments

Texture, shape, and color are the three elements of form. From the perspective of features presented by object surfaces, texture generally falls between shape and color (Ke, 1997), and therefore encompasses a fairly wide range. In terms of human senses, color and shape exhibit strong visual characteristics whereas texture tends to be associated with the sense of touch.

Texture and Texture Recognition

Webster's Dictionary defines the word "texture" as "the disposition or connection of threads, filaments, or other slender bodies, interwoven". Texture refers to the surface characteristics perceived by the visual and tactile senses. Examples include the grain of wood, the particles of gravel, and the softness of clouds. It is difficult to ideally define the texture derived in materials following surface treatment; however, from the perspective of reduction, one can define texture as the difference in attributes other than brightness, color, size, shape, and flashing frequency that an observer identifies between two surfaces. The stimulus patterns used in previous studies demonstrate that researchers view texture as a pattern comprising numerous densely concentrated elements of similar shape and size (Beck, 1966; Beck et al., 1987; Chen, 1999).

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Uniqueness of Texture Perception

Texture refers to the surface features of an object, and unlike color and shape, it is closely associated with the sense of touch (Horn, 1974). When the constituent parts of an object's surface are extremely fine, texture can be regarded as nearly the same as color. However, when the constituent particles are larger, the feeling of texture approaches that of shape. Thus, the feeling of texture in form can be categorized as both visual and tactile. The former is accumulated from experiences of the skin, including pain, pressure, and temperature. Thus, the height, thickness, sharpness, hardness, shape, and configuration of the particles as well as the weight and surface temperature of the object all influence tactile texture. For example, the feel of wood or metal will generate different tactile sensations and perceptions due to differences in surface as well as object characteristics. Visual texture is generally a visual effect stimulated through tactile experiences, including the arrangement, direction, and formation of surface particles, the spacing between particles, and the distribution density of the particles (Julesz, 1962; Julesz, 1975; Julesz, 1981). Once visual experience has been gained, one can feel texture simply by sight. The factors influencing visual texture also include exclusively visual characteristics, such as the transparency of the object and luster (the conditions of light reflection on the surface) (Ke, 1997).

METHODOLOGY

This study used visual textures to create images in the minds of subjects. Our primary objectives were to examine the relationship between texture and image to determine whether different textures create different images and whether subjects differed in their perceptions of textures according to their gender or educational background. We also sought to identify the factors and dimensions from which these perceptions should be evaluated.

Adjective Selection

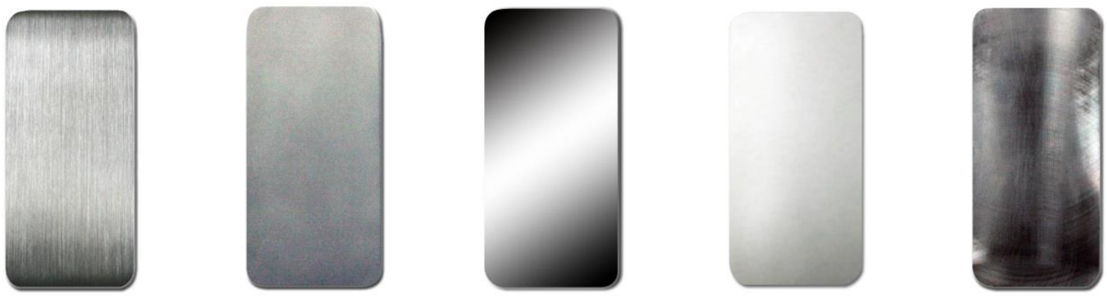
Adjectives can be used to describe images and feelings. The first stage of this study therefore involved the selection of image terms suited to our research theme. Because we investigated the perception of textures, we selected, as test scales, terms describing texture and those describing the feelings that textures evoke. We collected 120 adjective pairs describing texture from daily life, conversations between salespeople and customers, trade and industry magazines, and theses, and dissertations. Six postgraduates with backgrounds in design were invited to select 50 suitable pairs of opposite adjectives. We then invited five experts, comprising teachers and designers with more than 10 years of experience in design, to trim the selection down to 15 adjective pairs as the image terms used in the study (Table 1).

Table 1. Sixteen scales for texture image testing

1.Variable - Monotonous	6.Personalized - Popular	11.Natural - Artificial
2.Industrial - Artistic	7.Soft - Rigid	12.Extravagant - Simple
3.Trendy - Traditional	8.Curved - Straight	13.Stable - Fluid
4.Organic - Geometric	9.High quality - Low quality	14.Dynamic - Static
5.Decorative - Practical	10.Light - Heavy	15.High-value - Low value

Test Samples

According to a global survey conducted by Google in 2012, the ideal smartphone screen size is between 4.3 inches and 4.7 inches. However, from the perspective of human engineering, previous experience indicates that female users may be more accustomed to smaller screens while male users favor the visual impact provided by larger screens. The differences in hand size and strength between the two genders may also be determining factors. We therefore employed an aluminum alloy surface close in size to an iPhone 5 (length 123.8 mm × width 58.6 mm × thickness 3.8 mm) as the test sample in our experiment. The textures tested included hairline finishing, sandblasting, polishing, and turning (Fig. 12). These are currently the five most widely used surface processing methods for light metal materials. The hairline finishing was completed in straight lines. The sand coefficient for sandblasting was 80, and we used a mirror polish for the polishing texture. In anodizing, we performed film processing; in turning, we drew curved lines using a lathe.



Hairline finishing	Sandblasting	Polishing	Anodizing	Turning

Figure 12. Five types of mechanical surface processing

For the content of the questionnaire, we employed the semantic differential (SD) method to measure subject responses. Using the 15 adjective pairs derived in Section 3.1 as evaluation scales, we employed a seven-point Likert scale scoring from 1 to 7 points from left to right for each pair of adjectives (Fig. 13). Using the changeable-monotonous scale as an example, a response closer to the changeable end would derive a lower score, with 1 point at the least; a response closer to the monotonous end would result in a higher score. A score of 4 indicated that the subject held no particular disposition or opinions in this regard.

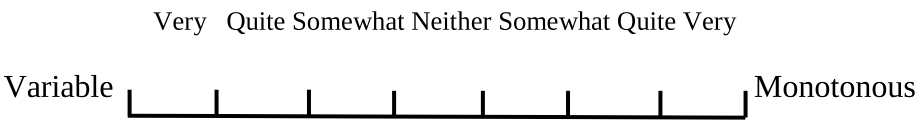


Figure 13. Example seven-point rating scale

Subjects

The subjects in this study comprised 120 students ranging from senior high school to graduate school between the ages of 16 and 30, evenly divided between females and males. We included students with backgrounds in design (including industrial design and visual communication design) as well as those with non-design backgrounds (Table 2).

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Table 2. Distribution of subjects

	Male	Female	Total
Background in Design	30	30	60
Non-design-related background	30	30	60
Total	60	60	120

Procedure of Experiment

The subjects were required to fill out five questionnaires. First, they observed the five textures in the experiment (by sight only; no touching) in the order of A, B, C, D, and E and then rated their visually derived feelings towards the textures using the 15 image scales.

RESULTS

Preliminary Statistics

In this section, we discuss the differences in the feelings among the 120 subjects towards the five aluminum alloy textures using the mean scores derived in each of the 15 scales.

In this section, we compared the subjects with design-related backgrounds to those with non-design-related backgrounds. For hairline finishing (Fig. 14), the subjects with design-related backgrounds presented the most significant responses in the Curved/Straight scale, where as the subjects with non-design-related backgrounds presented significant differences in Organic/ Geometric and Natural/Artificial.

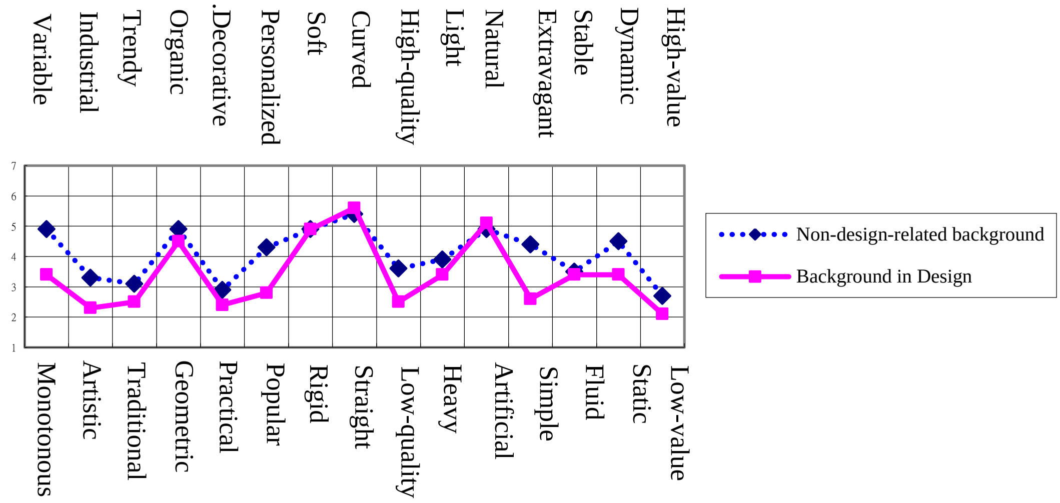

Figure 14. Mean score profiles of image perceptions towards hairline finishing from subjects with different backgrounds

In the texture of sandblasting (Fig. 15), the subjects with non-design-related backgrounds presented similar feelings to the subjects with design-related backgrounds in Organic/Geometric more significant differences in the other scales. The subjects with design-related backgrounds presented the most significant responses in Industrial/Artistic. The both groups of subjects made significant responses in High-Value/Low-Value.

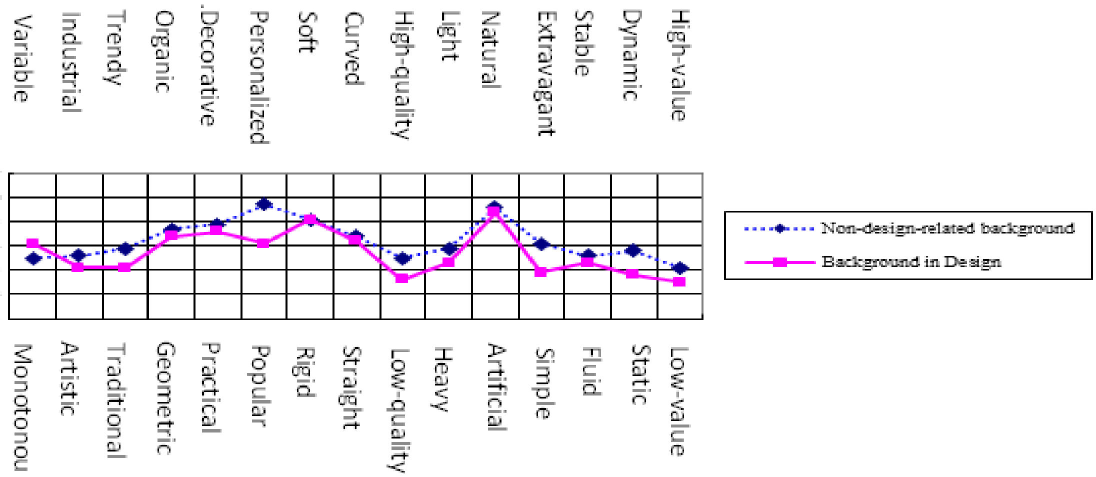

Figure 15. Mean score profiles of image perceptions towards sandblasting from subjects with different backgrounds

For the texture of the polishing finish (Fig 16), the subjects with non-design-related backgrounds presented similar feelings to the subjects with design-related backgrounds in Personalizes/Popular and in Natural/Artificial more significant differences in the other scales. The subjects with design-related backgrounds presented the most significant responses in High-quality/Low-quality. The both groups of subjects made significant responses in Soft/Rigid.

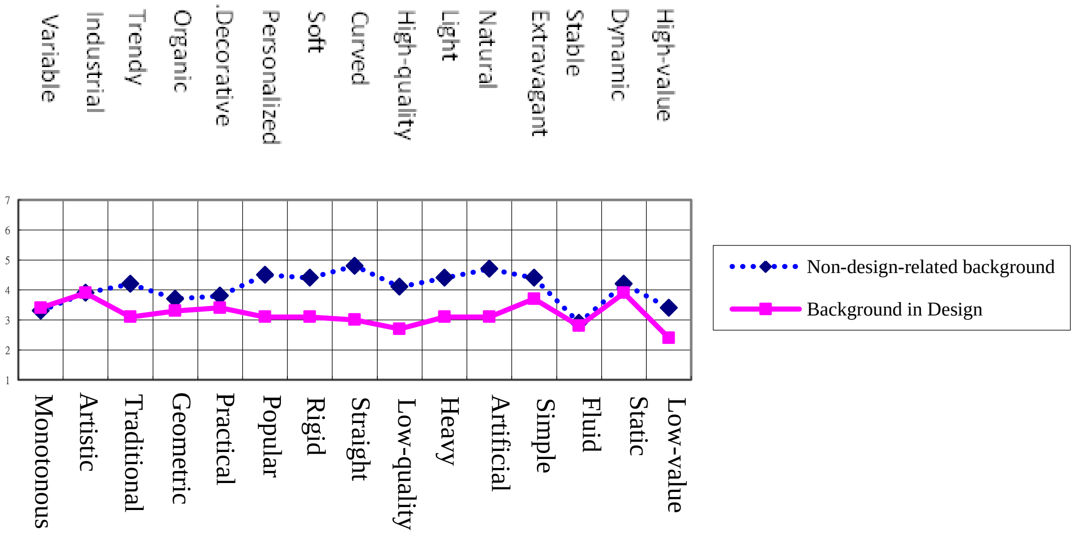

Figure 16. Mean score profiles of image perceptions towards polished texture by subjects with two different backgrounds

In the texture resulting from anodizing (Fig. 17), the subjects with non-design-related backgrounds presented similar feelings to the subjects with design-related backgrounds in Curved/Straight more significant differences in the other scales. The subjects with design-related backgrounds presented the most significant responses in High-Value/Low-Value. The both groups of subjects made significant responses in Variable/Monotonous and in Stable/Fluid.

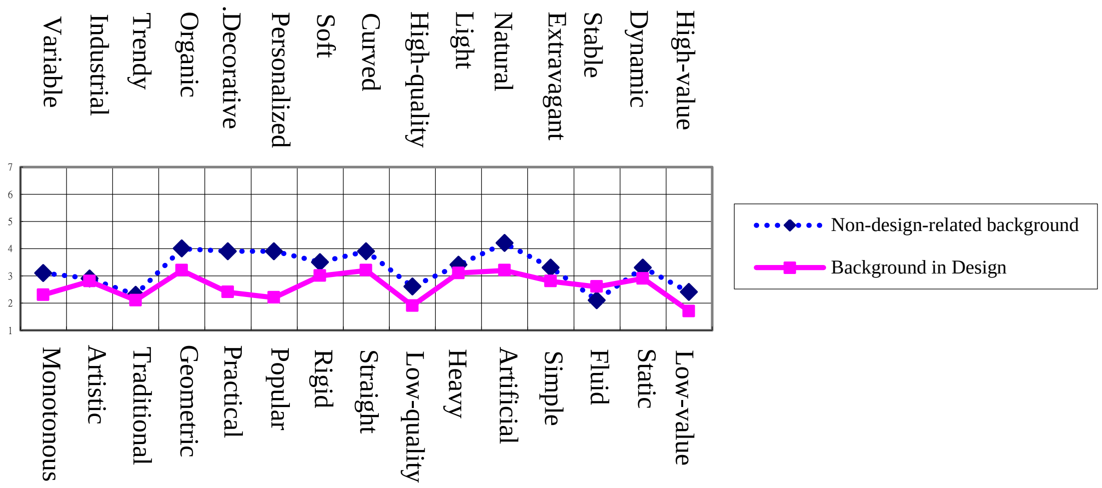

Figure 17. Mean score profiles of image perceptions towards anodizing by subjects with different backgrounds

In terms of the texture from turning (Fig. 18), the subjects with non-design-related backgrounds presented similar feelings to the subjects with design-related backgrounds in Dynamic/Static more significant differences in the other scales. The subjects with design-related backgrounds presented the most significant responses in the Extravagant/Simple. The both groups of subjects made significant responses in Variable/Monotonous.

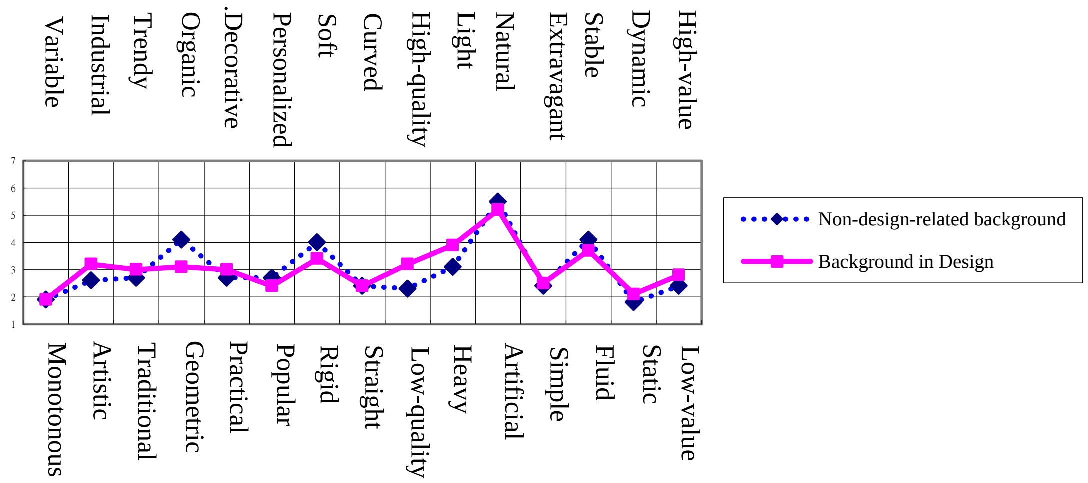

Figure 18. Mean score profiles of image perceptions towards turning by subjects with different backgrounds

The analysis of the preliminary statistics above showed no significant differences between the two genders or between subjects with different education backgrounds in terms of their perceptions towards the five aluminum alloy textures.

Factor Analysis of Texture Images

The data obtained from the subjects were subjected to factor analysis. According to Kaiser's criterion, we extracted factors with eigenvalues greater than 1, which resulted in three factors being extracted. In the scree plot shown in Fig.19, we can see that Factor 3 presents an elbow point, and Factors 1 through 3 show a steeply dropping curve, following which is a gentle trend. After the rotation in the principal component analysis, the correlations between the five textures and the three factors (factor loadings) are presented in Table 3, with a total variance of 72.73 % in which the variance of the first factor was the greatest at 32.43 %. This was followed by the second factor with a variance of 24.36 %, the third factor with 15.93 %.

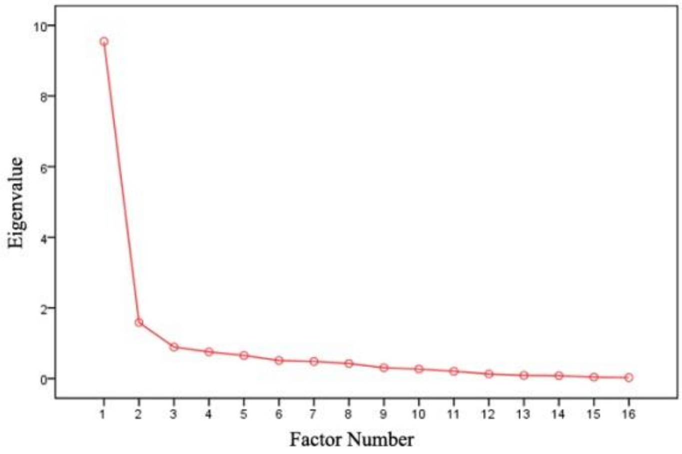

Figure 19. Scree plot

Table 3. Results of factor analysis: correlations between adjectives and three factors

	Adjective	Factor 1	Factor 2	Factor 3
Activity	Curved – Straight	.806	.212	.207
	Soft – Rigid	.767	.180	.104
	Natural – Artificial	.755	.189	.293
	Organic – Geometric	.744	.152	.401
	Dynamic – Static	.744	.428	.114
	Light – Heavy	.686	.383	-.087
	Variable – Monotonous	.619	.420	.375
Evaluative	Industrial - Artistic	.177	.848	.244
	Trendy - Traditional	.146	.812	.390
	High-value - Low value	.486	.764	.176
	Stable - Fluid	.437	.594	-.259
	High quality - Low quality	.530	.591	.240
	Extravagant - Simple	.512	.534	.422
Style	Decorative - Practical	.154	.161	.842
	Personalized - Popular	.218	.196	.822
Eigenvalue		8.20	1.48	1.22
Percentage		32.43	24.36	15.93
Cumulative percentage		32.43	56.80	72.73

Factors Explained

As shown in Table 3, the adjectives form three image perception factors. The first factor includes the seven (7) pairs of bipolar adjectives: Curved/Straight, Soft/Rigid, Natural/Artificial, Organic/Geometric, Dynamic/Static, Light/Heavy, and Changeable/Monotonous. We listed them as Activity factors, which contributed to a total variance explained of 32.43 %. The large (positive) factor loadings here indicate Curved, Soft, Natural, Organic, Dynamic, Light, and Changeable. The small (negative) factor loadings showed no significant differences.

The second factor included Industrial/Artistic, Trendy /Traditional, High-value/Low value, Stable/Fluid, High quality/Low quality, and Extravagant/Simple. We named these the

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Evaluation factors, which contributed to a total variance explained of 56.80 %. The large (positive) factor loadings here indicate Industrial, Trendy, High-value, Stable, High quality, and Extravagant. The small (negative) factor loadings showed no significant differences.

The third factor comprised Decorative/Practical, and Personalized/Popular. We named them the activity factors, which contributed to a total variance explained of 72.73 %. The large (positive) factor loadings here indicate Decorative, and Personalized. The small (negative) factor loadings showed no significant differences.

Analysis of Images in Semantic Space

From the descriptions above, we know that these three factors can form a semantic space. Based on the scores derived in the items in each factor (the five aluminum alloy textures), we mapped the corresponding coordinate points in the space as shown in Fig. 20, in which (A), (B), (C), (D), (E), and (F) contain the coordinate planes formed by the first factor and the second factor, the first factor and the third factor, and the second factor and the third factor.

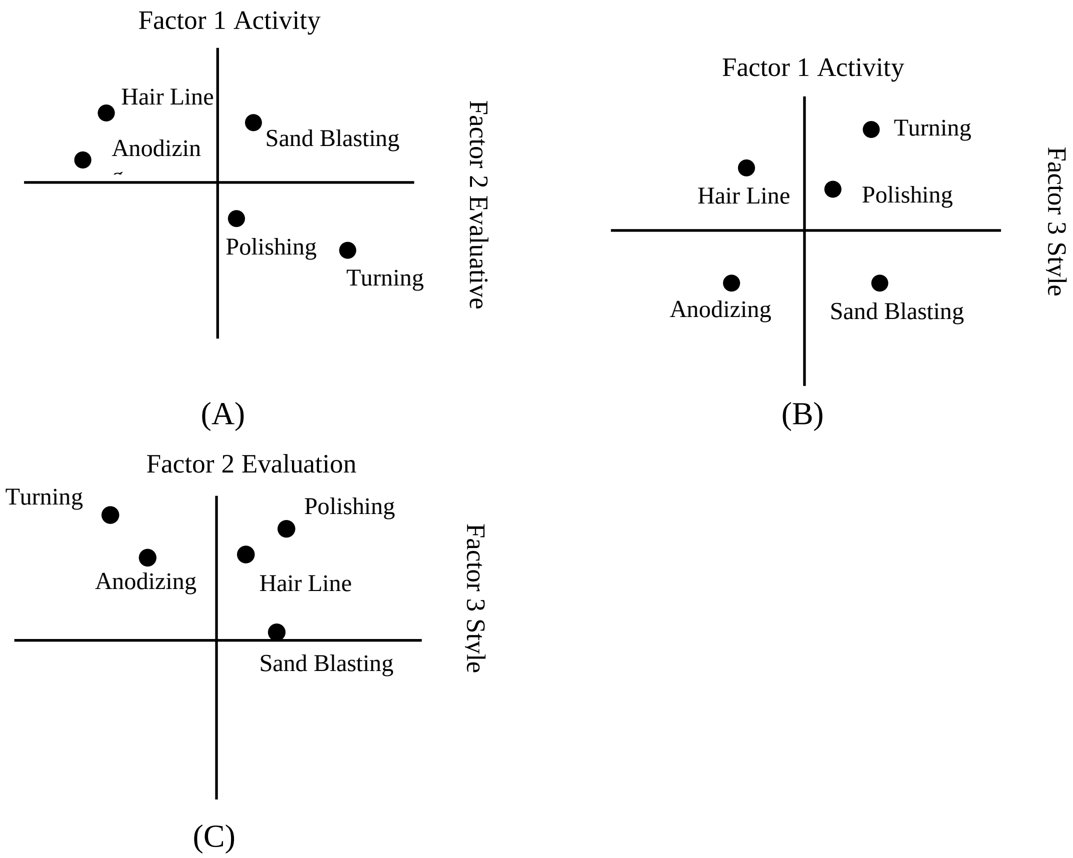

Figure 20. Spaces of average perceptions of subjects toward surface textures

Figure 20 shows that in the three dimensions, the five textures scored from highest to lowest in the following orders:

1. Factor 1 (Activity): sandblasting, hairline finishing, polishing, anodizing, and turning. This shows that in general, sandblasting obtained the highest praise.

2. Factor 2 (Evaluative): polishing, hairline finishing, anodizing, sandblasting, and turning. Despite the high score derived by the polishing texture, people generally consider polishing and hairline finishing as features with more potential or power.

3. Factor 3 (Style): anodizing, polishing, hairline finishing, turning, and sandblasting. This shows that people consider the textures resulting from anodizing and polishing to be more stylish and unique.

CONCLUSION

We drew the following conclusions from the tests in this study on the images perceived by the subjects toward the textures from five different aluminum alloy surface processes (hairline finishing, sandblasting, polishing, anodizing, and turning):

1. The subjects did not show significant differences in their perceptions of the five aluminum alloy textures in terms of gender.

2. In the five textures, the subjects perceived significant differences in Curved - Straight.

3. The two groups of subjects with different educational backgrounds displayed considerably different feelings toward the five textures, particularly in polishing, anodizing, and turning. In terms of their preferences, the five textures ranked polishing > hairline finishing > sandblasting > turning > anodizing.

4. The perceptions of subjects toward these textures can be expressed using a four-dimension space comprising four factors: Activity, Evaluative, and Style. In the Activity factor, the Curved/Straight scale scored the highest; in the Evaluative factor, Industrial/Artistic scored the highest; in the Style factor, Decorative/Practical derived the highest score.

ACKNOWLEDGEMENTS

This research is supported by Ministry of Science and Technology, Taiwan under grant MOST 106-2410-H-131-004 -. The authors are grateful for this research grant.

REFERENCES

[1] Beck, J. (1966). Preceptual grouping produced by changes in orientation and shape. *Science*, *154*, 538-540.

[2] Beck, J., Sutter, A., & Ivry, R. (1987). Spatial frequency channels and perceptual grouping in texture perception. *Computer Vis. Graphics Image Processing*, *37*, 299-325.

[3] Chen, I.P. (1999). *Texture identification visual and cognitive - visual perception and visual motion system*. Taipei: Ylib.

[4] Horn,G. F. (1974).*Texture:A design element*. Worcester, MA: Davis Publications.

[5] Julesz, B. (1962). Visual pattern discrimination. *IRE Trans Inf. Theory*, *IT-8*, 84-92.

[6] Julesz, B. (1975). Experiments on the visual perception of texture. *Scientific American*, *232*, 34-43.

[7] Julesz, B. (1981).Textons: the elements of texture perception and their interactions. *Nature*, *290*, 91-97.

[8] Ke, C.M. (1997). *A study on the visual and tactile image of material.* Yunlin: Department of Industrial Design Institute of Technology .

[9] Lai, G.Y. (1996). *Surface treatment of aluminum-manufacturing practical techniques.* Indonesia: Complex Han.

[10] Lin, W.K. (2012). *Monthly metallic materials. Metal center industry research group*.

[11] Liu, W.H. (2003). *Light metal material analysis of potential products and prospects.* Indonesia: The Ministry of Economic Affairs.

[12] Xu, Y.R. (2012). *Industrial materials.* Indonesia: Metal center IT IS plan.

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