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A Human Sensibility Ergonomic Design for Developing Aesthetically and Emotionally Affecting Glass Panels of Changing Colors

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Objective: To enhance user experience of the product by using "wow" materials and parts, a framework for participatory emotional design and evaluation was proposed and validated through a case study in this paper.

Background: Customers in recent days value a product which provides new feeling and images they want to get while interacting with it beyond its function, quality, and usability. Since the product consists of various parts and materials, "wow" materials and parts which can affect the customer's feeling and emotions are the essential components for changing the user experience.

Method: A framework for participatory and human sensibility ergonomic design was considered and applied on developing the aesthetically and emotionally affecting glass panels of changing colors. Design experts defined a target market for this multicolor glass panels and modified the existing designing goal. Constraints for this design modification were identified by market trend research and consulting with the company which owns the technology for checking out its feasibility. The company developed and provided prototype samples as well as their competing materials. Quantitative and qualitative evaluation of the emotional quality was conducted to validate whether the design goal was achieved successfully.

Results: The target market for the developing materials was defined as finishing for the buildings. The designing goal was set as to feed new visual sensation of clean and colorful images. The emotional quality of two different types of multicolor glass panels and an ordinary unicolor panel were evaluated quantitatively with semantic differential method. Results showed that the emotion of the subjects for the multicolor glass panels can be abstracted into two dimensions; named 'colorfulness' and 'harmony'. It was found that the developed samples got higher scores in emotional quality for both dimensions compared to the ordinary one. Age was found to be a significant factor for evaluating the emotional quality of colorfulness.

Conclusion and Applications: The proposed framework is a valid approach for enhancing the user experience of the product by participatory design of emotional materials and parts. This framework can be applied easily on the emotional design and evaluation of different materials and components.

Keywords: Human sensibility ergonomics, Wow materials, Participatory design, Multicolor glass panels, Satisfactory emotions

1. Introduction

In the previous days of product design, focus of design was placed on the function, reliability, and usability. However, it has evolved to include higher aspects of customer's needs including emotion (Walter, 2011; Kim and Choi, 2010). Emotional design is developing a product in a way that it could provide 'emotional satisfaction' that should be experienced by a user when interacting with that product by taking into consideration the higher needs of the user (Sun and Sun, 2008). Consumers prefer the product which conveys new emotions never experienced before and these feelings and affections become one of major factors influencing the consumer buyer behavior (Lokman, 2010). This user experience has proven as a determinant at the time of selecting between products and users are choosing the one that provides positive emotions in addition to fulfilling their functional needs.

Research on emotional product design started in the fashion industry first and soon became a general tool for identifying and realizing images of the product wanted by the market and individual customers. Emotional design pursues differentiation and diversification of the product in various ways such as changing their colors, materials, and finishing. According to previous researches, different feelings can be delivered depending on the texture of the materials even though the other design is identical (Kim et al., 2007); and feelings perceived by the user can change due to the difference in color or texture of the finishing materials (Choo and Kim, 2002). For example, if people receive positive feeling when touching a product, a bond is formed between them and the people is being more generous for the product. When people interact with the product, their level of satisfaction is determined as an abstracted feeling (Lévy, 2013), that is emotion and sometimes called as Kansei, and it is integrated by individual sensations from different sensory channels. After this process is experienced repeatedly, emotional quality of the product is stored in the user's memory as good user experience.

As the user experience for a particular product is established through the interaction while using it, researches have focused on improving the emotional satisfaction of the 'end' product. It is important, however, to develop individual parts and materials in a way that they could contribute to enhance the emotional satisfaction of the customers since the end product consists of various parts and materials (Kwon et al., 2013). Some materials and parts really works for changing the emotional satisfaction of the end product remarkably, and they have been called as "WOW" materials and design. (WOW Design Infographic on Vimeo, 2013) The power of wow materials and design is that they can be applied to various product in various ways and thus they have a bigger impact than the emotional design of a single end product.

A fair number of companies have been trying to involve emotional design approach in their R&D process. However the outcome can cause serious financial damages for the company if these emotional designs are failed to identify the user's needs and realize it through their manufacturing process. One risk factor for these materials and parts manufacturing companies is that they do know about the technology to manufacture, but barely know the trend of target market, their positions and directions to improve their values in the market. In most cases of small and medium sized companies, they cannot afford to manage their own design and evaluation team for seeking chances and make their product more market-friendly and valuable. It is not easy for the design and evaluation experts outside the company to give ad hoc advices in the development process without having proper understanding about the materials and its manufacturing process. There should be a way of occupying participatory design and evaluation approach by design and engineering as well as industry collaboration.

The purpose of this study is to propose and establish a framework for participatory design and evaluation to develop high quality emotional parts and materials. The proposed framework was validated through a case study of developing the aesthetically and emotionally affecting glass panels of changing colors that are going to be released as finishing materials of the buildings.

2. Method

A participatory design and evaluation framework is proposed to develop emotional parts and materials as shown in Figure 1. This framework aims to develop market-friendly materials and parts by integrating and balancing various aspects in terms of market trends, company's technological capabilities and knowledge from expert engineering group (human factors engineers and designers) as shown in Figure 2.

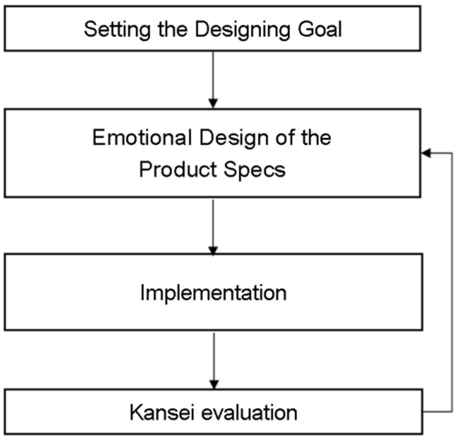


Figure 1. Process occupied by the participatory design framework

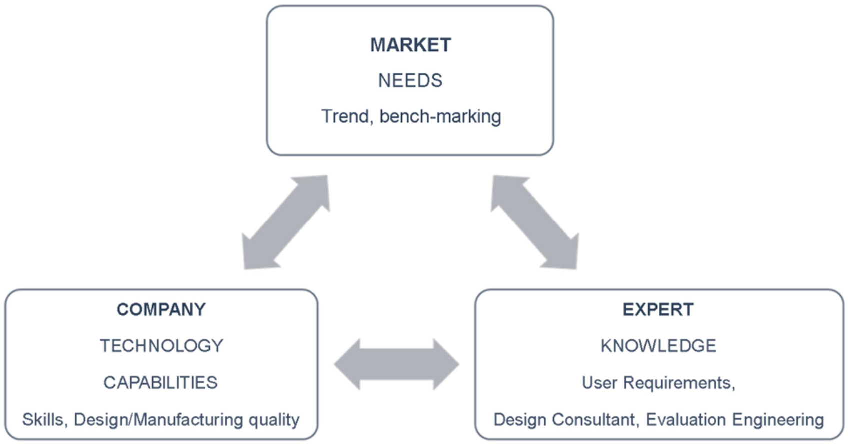


Figure 2. Three components involved in the participatory design framework proposed

The full process of the proposed framework consists of 4 steps: 1) Setting the designing goal, 2) Emotional design of the product specifications, 3) Implementation, and 4) Kansei evaluation. For each step, there are tasks carried out in three categories individually; market, company and experts. The individual outcomes of each task are adjusted and integrated in a way that can be used as inputs for the next step.

The first step, setting the designing goal, involves finding out the constraints for setting the designing goal. At this stage, company identifies current technical capabilities and its own design goal, designers select a target market based on the understanding of the company's capability limitations and perform analyses that include, among other tasks, the study of trends for CMF market (Colors, Materials, and Finishing) and user requirements analysis. Afterwards, the outcomes from these different categories are integrated by cooperation between the designers and company. Then it is defined the emotional design goal, also known as target image, as well as the responsible sensory channel to be used as a sensation trigger.

The second step is named as emotional design of the product specifications, and the feasibility of the designing goal is considered on this stage. Designers play an advisory role as consultant by taking into consideration the target market and technological capabilities of the company. Company defines the engineering design parameters of the prototype to achieve the emotional goal.

On the third step, implementation stage, the company manages the manufacturing process to realize the emotional design specifications developed on the previous stage. The company produces the prototypes of the newly developed materials or parts and provide comparative samples against the prototypes to be evaluated.

On the fourth and final step, Kansei evaluation, with quantitative and qualitative methods, is conducted on the given prototypes and comparative samples in order to measure the emotional quality of the developed samples. The steps followed on this evaluation process are shown in Figure 3. The evaluation process begins by human factors engineers who prepare a Kansei (human sensibility ergonomic) evaluation form which will be utilized in the semantic differential method in order to evaluate, with a survey, the implementation of the emotional target (Wang, 2009).

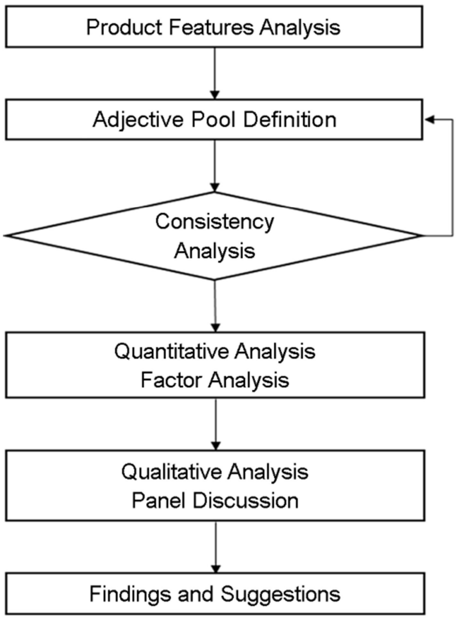


Figure 3. Detailed evaluation process for the emotional quality

The Kansei evaluation starts with collecting adjectives which are conceived appropriate to express the goal emotions by analyzing a product characteristics (in this case prototypes), each adjective should be defined with its opposite pairing adjective. A consistency analysis of adjectives with product features should be conducted for extracting final set of adjective pairs. Each pair of adjectives is utilized as measures for quantifying the emotions with seven point scale in the semantic differential method (Lokman and Ibrahim, 2010).

In order to get more insights on gender and age differences; a stratified sampling was carried out to aggregate the subjects involved in the quantitative evaluation. The participants are made up of seven males and females respectively in each age groups of decadal changes from their twenties to sixties, and making it a total of 70 people. These subjects are denominated as the non-expert group; they are not designers nor glass experts, rather ordinary customers without prior experience to the product. After executing the survey, the responsive data from participants was collected and analyzed using statistical data analysis methods (Han and Oh, 2010; Roh and Ryu, 2005; Chung, 2001).

In addition to the non-expert group of subjects, two additional groups of expert designers also evaluated the samples in a qualitative way. The first expert group consisted of designers who have been involved in the project and the designers belong to the second expert group do not have shared any information regarding the project before the evaluation. With the expert feedback obtained in this qualitative evaluation and panel discussions, the results from the non-expert group is validated and investigated if there is difference in the result between the non-expert and expert groups. With the insights gained with the quantitative and qualitative analysis, suggestions and feedback is provided for the company.

3. Results and Discussion

3.1 Setting the designing goal

Korean construction industry has grown rapidly since 1960's. However, the focus of the market has been rearranged after the

	
HARPA CONCERT HALL Location: Reykjavík, Iceland, 2011	VERNERJOHNSON'S MUSEUM Location: Overland Park, KS, 2014
	
MUSAC - Museo de Arte Contemporá-neo de Castilla y León Location: León, Spain, 2007	DAEGU WORLDCUP STADIUM Location: Daegu, Korea, 2011

Figure 4. Recent trends in applying color glass panels on the buildings

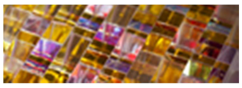
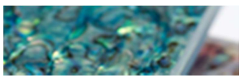
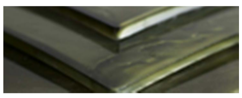
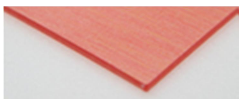
financial crisis to include not only the functional aspects of a product but also the concept of aesthetics and energy efficiency (Park, 2010).

In case of architectural glass industry, it is highly dependent on the economic condition of the construction business. Since the recent business depression of domestic and foreign construction business, the glass industry has also suffered a slowdown. Nonetheless, there are a number of skyscrapers and buildings constructed with architectural glass around the metro cities as shown on Figure 4. They have drew out people's attention in a positive way and have even been included as hot places for sightseeing.

Recently, functional glass have been applied as finishing materials of the buildings but color glasses are rarely found yet. Moreover, if the building exterior would be constructed with changing color glass panels, the edge of building design could expand to the direction of market trend (Park, 2010). Furthermore, it is possible to affect people's emotions by using colorful panels with the image of the building that designers as well as the customers have dreamed of (Cheon, 2013). Therefore differentiation in colors, materials or finishing (CMF) is a significant element for positioning the products in a better place in the market, because it will bring brand new experience for the people in terms of design and sensible communications.

The CMF trends are identified on the basis of announcements made by KCC Trend Pulse 2015~2016, Monthly Design, Meta-Trend of Samsung SDI materials, and categorized into three themes; Super Simple, Warm Metallic and Unexpected Surprise. Research and benchmarking was conducted on the state of the art glass materials or similar products in the current market. As shown in Table 1, many companies implement numerous patterns and colors by adding a touch of various ingredients to glass materials recently (KCC Color and Design Center Homepage CMF Trend 1, 2015; KCC Color and Design Center Homepage CMF Trend 2, 2015; Maison et Object, 2015).

Table 1. Materials for the benchmarking

Material (Manufacturer)	Image
Zari Reflections (Sensitile)	
Glass (Lhotsky)	
Sonite Cosmos (Sonite Innovative Surfaces)	
Shells (Hale GmbH)	
Karei (N Cubed)	
LumicorTM (Lumicor)	

User requirement analysis was carried out with a literature survey for the glass panels, and by interpreting the local users' reviews. As a result, five major user requirements were established as shown in Table 2.

Table 2. User Requirements

Needs classification	Content
1. Requirements for public needs of buildings	Requirements for public autonomy in cultural aspect of buildings
2. Requirements for deconstructive aesthetics that surpasses efficiency	Atypical aesthetics which accomplishes multi-dimensional and multi-valued requirements
3. Requirements for trans-borderline of space	Meaning of surface as a device for reproducing uncertainty and utilization of glass material
4. Requirements for superimposed feeling which delivers vitality	Superimposition of image and glass as a tool to connect preferences
5. Experience in space of superimposed image	Place of superimposed image based on variability of color

Finally, the goal for design was set, as summarized in Table 3, on the basis of these results that came from market characteristics, CMF trend and the user requirements analysis performed.

Table 3. Goal definitions for the emotional design

Analysis of market characteristic	CMF Trend, research
Analysis of product characteristic	Technology and design capabilities
Analysis of user requirements	Environment and experience
New visual sensation of clean and colorful images on glass	

3.2 Emotional design and implementation

In the emotional design step, the designers analyzed the available company technology and advised to produce materials by mixing colors and embossing patterns. With the advice from expert designers, the company set out to develop 3 or 4 kinds of color glass sample prototypes which would be expected to yield higher emotional satisfaction of the consumers. The designers and company engineers identified the design constraints and converted them in engineering parameters as like difference in color (ΔE) ≧ 20, contact angle (Degree) ≧ 95˚, and adhesive power in 0/100.

In the implementation stage, the company manages manufacturing process for realizing the design into product and two different prototypes (they will be referred as sample A and B from now on) are arranged by the company. A traditional transparent glass panel (sample C) is also supplied by the company for the purpose of comparative evaluation. Sample A is a multicolor panel with embossing pattern on the surface, and sample B is only a multicolor panel without pattern. The characteristics of the three samples to be evaluated are illustrated on Figure 5. Though the application purpose of the materials analyzed is on buildings exteriors, the samples were manufactured in 20 x 30cm dimensions for the convenience of experiment.

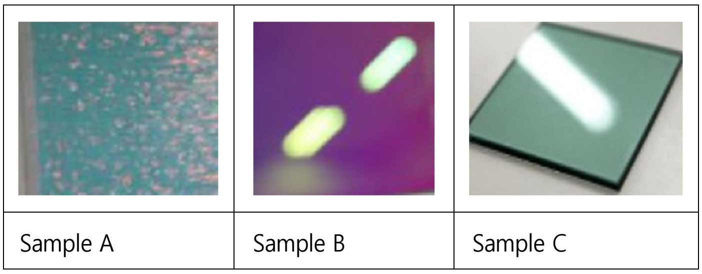


Figure 5. Images of the samples tested

3.3 Kansei evaluation

In order to apply the semantic differential method on evaluating subjective emotions attained from interactions with the color glass panels, it was extracted a pool of adjectives that are conceivable to express the feelings coming from different features and characteristics of the color glass samples. The number of adjectives in the initial pool was more than 70 pairs, but 30 pairs of final adjectives were draw out on the basis of their consistency and efficiency of use through a pilot experiment. These final 30 pairs of adjectives utilized in main experiments are summarized in Table 4.

Table 4. Final adjective pairs selected

Positive	Negative	Positive	Negative
Concise	Disordered	Prominent	Flat
Fresh	Withered	Open	Close
Bright	Dark	Well-matched	Ill-matched
Unique	Common	Refreshing	Unpleasant
Elegant	Crude	Luxurious	Cheap
Vivid	Blurry	Glossy	Faded
Balanced	Shaky	Delicate	Shoddy
Natural	Unnatural	Nice	Loutish
Sophisticated	Crude	Unconstrained	Restrictive
Neat	Messy	Elaborate	Shabby
Fine	Poor	Diverse	Monotonous
Drafty	Stuffy	Brilliant	Gloomy
Creative	Boring	Mysterious	Ordinary
Light	Heavy	Dynamic	Static
Unusual	Banal	Fancy	Shabby

Factor analysis was performed on the subjective responses from the semantic differential evaluations. It is to identify the abstracted and interrelated structure of human emotion with respect to the testing materials. The result from the analysis showed that the subjective emotions can be abstracted within only two different factors (percentage of variance = 0.567). The reduced factors and their belonging adjectives are summarized on Table 5.

Table 5. Factor analysis results

Evaluation standard	Paired adjectives	
Factor 1: Colorfulness	Unique	Common
	Luxurious	Cheap
	Nice	Loutish
	Diverse	Monotonous
	Prominent	Flat
	Sophisticated	Crude
	Mysterious	Ordinary
	Unusual	Banal
	Elegant	Crude
Factor 2: Harmony	Concise	Disordered
	Balanced	Shaky
	Neat	Messy
	Vivid	Blurry
	Natural	Unnatural
	Light	Heavy

Factor 1 is named as 'colorfulness', and it seems to abstract and represent emotion in regards to variability of the materials in terms of colors in visual sensation with different fields of view and viewing angles. While factor 2 is named as 'harmony', and it comprehends emotion that subjects perceive in terms of visual balance and equilibrium of the materials. Average factor scores of the three samples are depicted in two dimensional emotion map shown on Figure 6.

The average factor scores show that the subjective emotions in terms of colorfulness (axis X) and harmony (axis Y) are different with respect to the three samples in consideration. In the comparison between samples A and B, the emotional gap in terms of colorfulness is $\Delta X=0.118$, and that of harmony is $\Delta Y=0.434$. It means that sample A has better emotional quality in average compared with sample B for both dimensions. The emotional gap between the samples are getting bigger when we compare the samples A and C. The differences in the average for the two samples are $\Delta X=1.613$ and $\Delta Y=0.781$, which means sample A is much better in emotion of colorfulness and harmony against sample C. In comparing sample B with C, the average differences are $\Delta X=1.495$ and $\Delta Y=0.347$ and it means that sample B has better quality than sample C on both dimensions. Therefore, sample A exhibits the best emotional quality in terms of colorfulness and harmony; with its quantitative evaluation followed by sample B and C, respectively.

To identify if these differences in average emotional qualities are statistically significant, the analysis of variance (ANOVA) tests were conducted on the subjective responses with respect to each dimension of the emotional quality. In addition to the ANOVA, the

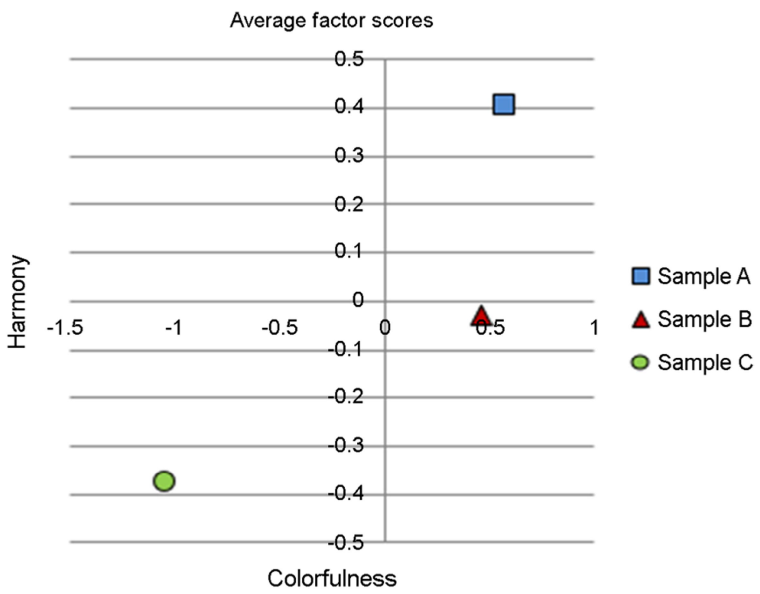


Figure 6. Average factor scores of the samples

distribution of subjective factor scores for the samples were analyzed and the results were illustrated in Figure 7 and 8.

On Figure 7, factor scores in colorfulness dimension among the subjects is summarized in the box plot. This graph shows that the factor scores in this emotional dimension follow normal distributions. Though there were a few extreme values observed, the wings of individual boxes are fairly symmetrical and having similar level of dispersion. It means that the subjective responses are quite reliable and thus the evaluation process is valid. The result of ANOVA for colorfulness provides evidence that there is a statistically significant difference in the emotional quality of the three samples (p-value < 0.001). When it comes to comparing only samples A and B, there is no significant difference in the emotion of colorfulness between them (p-value $= 0.271$). There is a statistically

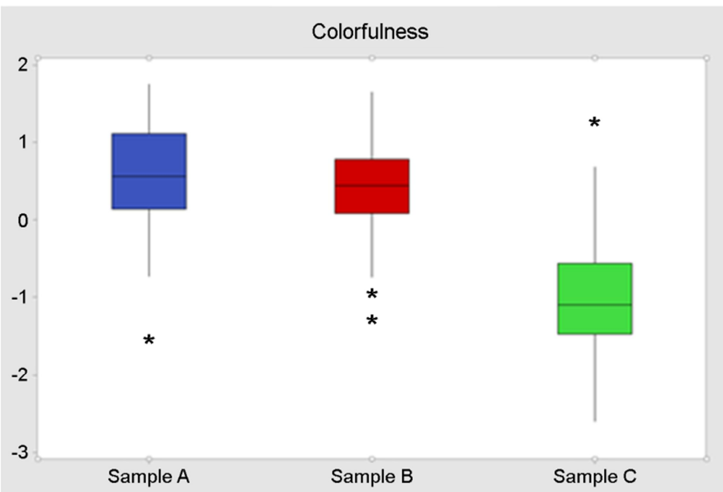


Figure 7. Boxplot of the factor scores in terms of colorfulness

significant difference between sample C and samples A & B (*p*-value < 0.001). With this result it can be said that samples A and B, in comparison with sample C, are developed in proper way to satisfy the design goals for enhancing the emotional quality at least in terms of colorfulness.

The box plot for factor scores in harmony is shown on Figure 8. The factor scores for harmony also showed normal distributions but their dispersions are larger than those of the colorfulness. The sample A showed a significantly larger dispersion, ensuring that the subjective differences are most wide for this sample in the dimension of harmony. The result of ANOVA for harmony provides evidence that there is a significant difference in the emotional quality for the samples evaluated (*p*-value = 0.000). On Figure 8, it seems that samples B and C exhibit similar results; however, their averages are statistically different (*p*-value = 0.017). Sample A received a significantly better score on this parameter compared to samples B and C (*p*-value < 0.001). With this results it can be extracted that sample A and B induces a better emotional response on subjects in terms of the harmony factor.

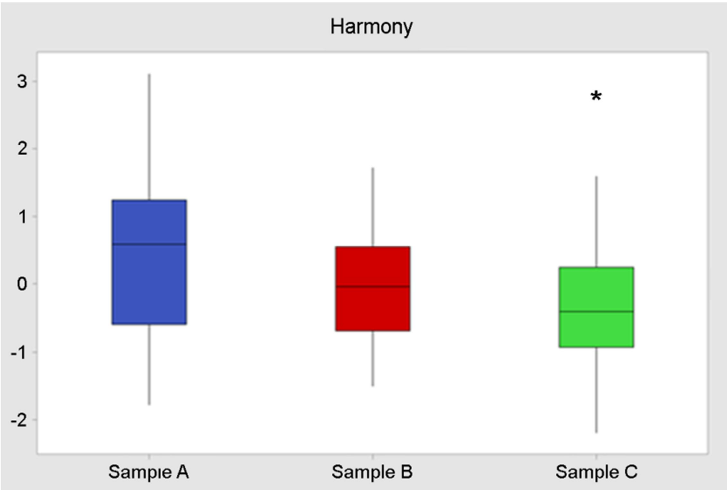


Figure 8. Boxplot of the factor scores in terms of harmony

The difference of emotional response in terms of colorfulness and harmony for gender and age is depicted on Figure 9 and 10, respectively. The ANOVA performed on gender effect provides evidence that there is no statistically significant difference in factor scores for colorfulness (*p*-value = 0.594) nor harmony (*p*-value = 0.172). However, it can be seen on Figure 9 that when it comes down to sample A in the emotion of harmony, the factor scores of the female subjects are considerably lower than those of the male subjects. For the male subjects, sample A received a noticeably higher factor scores than sample B, which shows the preference of the males for the embossing patterns in feeling harmony.

The analysis of variance carried out for age showed that there is a statistically significant difference for colorfulness (*p*-value < 0.001) and harmony (*p*-value = 0.008). When the colorfulness is analyzed, the effect of age on samples A and B was not significant, while that for sample C was considerable. This result comes from the fact that, as can be seen on Figure 10, younger subjects tended to provide a much lower values for this comparative sample C. It ensures the preference of younger age group for the developed prototypes in the aspects of colorfulness. Considering the other dimension, harmony, the difference in emotional value between samples was wider for the younger group, while this variance tended to go down with the age increased. Another finding is that sample A received lower values than sample B and C for the age group of sixties (the oldest),and it could be caused from conservative tendency in feeling emotions in this age group. In summary it can be said that the prototype samples developed on the basis of new design goal are more appealing than the traditional sample especially for younger people.

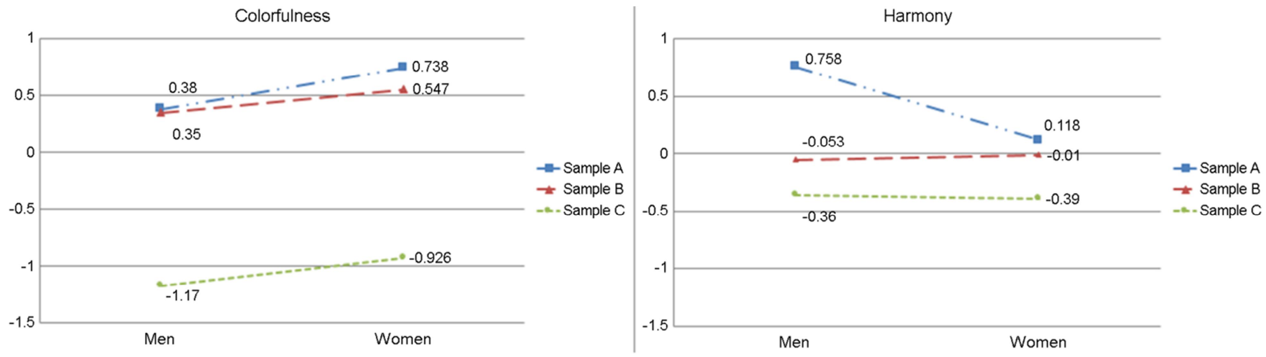


Figure 9. Gender effect on emotions of the tested materials

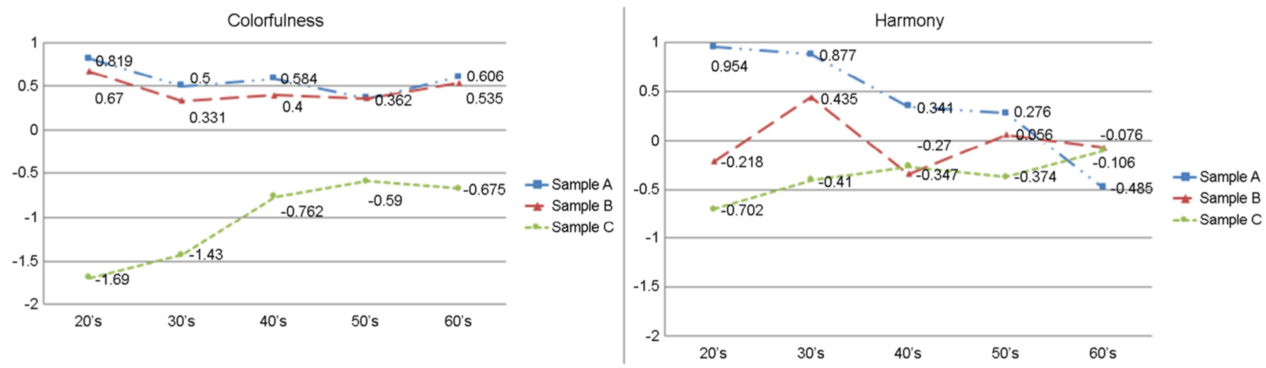


Figure 10. Age effect on emotions of the tested materials

A qualitative evaluation of the emotional quality was also conducted by two different group of experts consisted of designers who have or have not been involved in the stages of this study before the evaluation, respectively. The reason for this grouping was to avoid the effect that prior knowledge about the materials and manufacturing process can yield in the evaluation. The experts were asked to evaluate the emotional quality of the prototypes and comparative sample on the basis of their own expertise whether the given samples are achieving the design goal. After this individual evaluation, the designers had a panel discussion for sharing their opinion about how are the emotional quality of the samples and how can it be improved more.

The experts agreed that the developed prototypes have better emotional quality than the comparative sample, but there was one result that was not consistent with that from the non-expert group. The expert designers can tell the difference in emotional quality more deliberately between sample A and B whereas the ordinary subjects cannot do it well. The experts' explanation for this is that it comes from difference in the power of imagination between the expert and non-expert group. When it comes to building materials, the subjective emotional quality can vary with what part of the building will be covered and how large is the size of the materials on the real building even though the same materials are going to be applied. Therefore, it is not easy for ordinary people to imagine what the final appearance of the buildings would look like with the given materials since they have not been trained to get that level of visualization. This might be the reason why the subjects in the non-expert group had trouble to make a difference in evaluation between sample A and B. It is noted that the emotional quality of the developed prototypes got better scores in emotional quality from both of expert and non-expert groups. It means that the emotional quality of the prototypes developed in this study is improved even sufficiently enough to be told by non-expert group despite of their lack of sensitivity.

4. Conclusion

To enhance user experience of the product by using "wow" materials and parts, a framework for participatory emotional design and evaluation was proposed and validated through a case study in this paper. The framework proposes engineering and design collaboration from three different point of view; market, company, and experts, and adapted a human sensibility ergonomic approach, so called Kansei evaluation for assessing the emotional quality of the designed parts and materials.

To create higher emotional values of the glass materials, glass panels of changing colors were designed and manufactured as a "wow" finishing materials for the buildings. Two different prototypes of color glass panel were designed and realized on the basis of the design constraints and its goal to feed new visual sensation of clean and colorful images. The prototypes were compared with a comparative sample in terms of two different emotions called colorfulness and harmony. In terms of colorfulness, it was found from the quantitative and qualitative evaluation that the developed prototypes are better in this emotional quality than the comparative sample. This result supported that glass panels of changing colors are effective to draw out emotion of colorfulness from the customers. It is expected that the emotion of colorfulness is to be drawn out effectively with this design from both of male and female customers because there are no significant gender effect on this emotion. Considering the significant age effect, this design would be more effective for younger customers to draw out positive emotion of colorfulness.

The effectiveness of the design in creating new values is also supported by the fact that the developed prototype sample A got higher scores than sample C in terms of harmony as well. However, an additional way for enhancing the design is needed to consider in the next stage of design, because of the large variance in the subjective emotional quality of harmony compared with those of colorfulness. Gender effect was not significant for the emotion of harmony, but more through consideration is needed when using the glass materials with embossing patterns and changing colors. It is because the gender effect is prominent only for this type of glass panel, sample A, and thus the effect of gender and age should be considered in the design when using this type of materials.

The excellence in design of the developed prototypes is reinforced by the result from the evaluation and their panel discussion of the expert designer groups. The advisory comments from the experts should be kept in mind during the design of the building

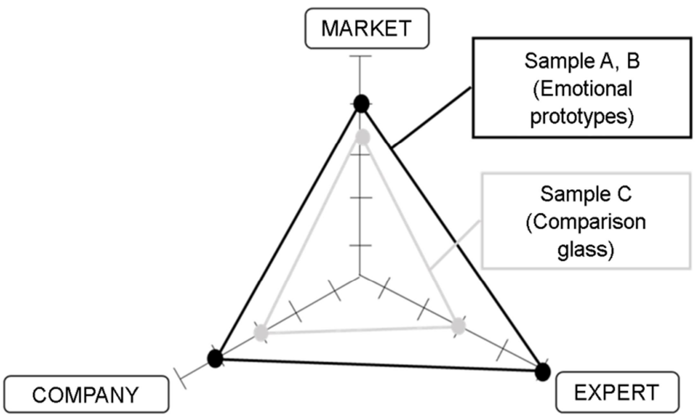


Figure 11. Positioning Map of the tested materials

materials. The difference in experience and power of imagination in space among customers can cause difference in emotions; and thus how to handle this difference is one of key factors for successful design.

Figure 11 summarize the position of the samples tested in this study with three different points of view. The excellence in design of the developed samples A and B compared with traditional sample C is clearly viewed from this figure in all viewpoints of the three categories; market, company, and experts. It can be concluded that the glass panels of changing colors developed in this study are successful to achieve the designing goals to feed new visual sensation of clean and colorful images. It is encouraging that emotional quality of the developed prototypes is evaluated higher by the expert designer group who know where and how to apply these materials.

Two things could be pointed out as weaknesses of this study. One thing is related with fidelity of the evaluation. Though the developed materials are going to be applied on the buildings as finishing materials, the emotional quality evaluation was conducted on the glass panels itself and thus the real images of the building was not visualized to the subject for direct interaction. Second thing is related with the fact that the size effect of the glass panels are not controlled or considered in the study. As the experts pointed out, the size of the glass panel is one of the design parameters that yield different feelings of the customers. With limited power of imagination, it might be hard for the ordinary customers to get more realistic emotions from the glass panels which is not exactly same with the real application.

Despite of these disadvantages, it was validated the effectiveness of the proposed framework for participatory design of the parts and materials. A multidisciplinary engineering and design team executed this framework collaboratively for enhancing the emotional quality of the parts and product, and this framework can be applied on more diverse parts and materials design. It is expected to develop more valuable parts and materials with this approach that can fulfill higher aspects of customer's needs including emotions and user experiences.

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