The characteristic of image quality perception of elderly group: according to the comparison with adult group

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ABSTRACT
This study examined the image quality preference of the elderly group. The subjects were divided into adult group and elderly group based on their age, and subjective image quality evaluation was performed. In result, two significant differences were found according to the age group. First, the elderly group evaluates image quality based on sensory stimulation (sharp, clean), which involves less complicated cognitive processes compared with the adult group. Next, the degree of image quality preference of the elderly group was not significantly influenced by decrease and increase of brightness and saturation compared to adult group. Notably, when brightness increased significantly, the tendency of image quality preference of elderly group remained high unlike the adult group. This confirmed that it is necessary to increase the brightness of the image in order to satisfy the elderly group’s image quality preference at a high level compared with the adult group.

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1. Introduction
The competition in the display industry is becoming more intense, and consumers are demanding a sharper and more realistic content experience. A number of studies have been conducted taking into consideration the image quality preference of viewers in the display and content development stages. These image-quality-related studies mainly targeted subjects in their 20s and 30s (young adults) as well as middle-aged people. On the other hand, there were few studies dealing with image quality preference that targeted groups not familiar with IT, such as the elderly group. According to the research by Statistics Korea [1], the TV viewing hours of baby boomers born between 1955 and 1963 were two to three times higher than those of their children as of 2014. The hours of watching display media of elderly people, who have more free time, have continuously increased, and the type of display that elderly people experience has also diversified. Following the recent retirement of baby boomers, the elderly group with economic and spending power has expanded. Following these changes, it is necessary to conduct studies targeting the elderly group in the display market, which is becoming segmented based on contents and user experience. The visual and cognitive functions of the elderly group are inevitably different from those of the adult group due to the changes influenced by aging. Also, there is a possibility that the image quality preference of the elderly group will turn out different from that of the adult group according to the existing display experience and sociocultural background. This study intended to divide the subjects into the adult group consisting of subjects in their 20s and 30s and the elderly group made up of subjects 55 years or older, to examine the image quality preference of the elderly group as distinguished from that of the adult group.

2. Theoretical background
2.1. The vision of elderly people
According to past studies, aging affects a person’s visual perception functions. In the eyes of elderly people, the transparency of the crystalline lens declines due to aging. In physiological terms, the changes due to aging are manifested on the level of the photoreceptor. When a person ages, the number of cone cells is stably maintained while the number of rods decreases. For this, the rods react...
more sensitively than the cone cells with age [2]. With the decreasing number of rods, the visual sensation of elderly people becomes poorer and dimmer compared with that of younger people. According to the previous studies, the decrease in the visual perception function due to aging is prominently manifested in the perception of contrast. The sensitivity in contrast perception decreases with age [3,4]. In addition, the density of the retinal ganglion cell layer, which ultimately transmits optical information to the brain, also decreases with age [5]. It was proven that the visual sensation of an elderly person may have different characteristics compared with the visual senses of a young person due to the changes on the level of the visual cells following the aging process. Such changes particularly influence the perception of contrast. There were also studies that examined the effect of aging on color and saturation perception, apart from brightness and darkness, among the color attributes. The study by Knau and Werner [6] showed aging-related losses for the long-wavelength (L), medium-wavelength (M), and short-wavelength (S) cone mechanisms on the level of the photoreceptor. Also, Carp [7] reported that the visual sensation of the elderly has a characteristic of not being able to distinguish the difference in saturation at the same brightness level due to the crystalline lens degeneration. These previous studies showed that aging causes loss of visual functions, which causes some loss of contrast, color, and saturation perception among the visual functions.

2.2. The perception of elderly people

Various studies have been conducted on the changes in the cognitive functions due to aging. Physiological studies on cortical changes due to aging have been conducted in the field of brain science. Peters et al. [8] confirmed the decrease in cell density and synapse in layer 1 of V1 in the visual cortex of monkeys. Such changes appear to be related with the aging-related behavior scale of cognitive decline beyond the visual cortex [9]. In other words, this implies that the decrease in the cell density of the brain cells due to aging may affect the cognitive decline of elderly people.

Marr et al. [10] proposed the modularization of perceptual information for a study on cognitive processes for visual perception information. An image can be disassembled into several components depending on the objects in the image. The components have five main properties: luminance, color, motion, texture, and depth. All the components of an image are derived from these five basic properties. First, luminance and color are the primary properties (first order) that are perceptually processed. Motion, texture, and depth are the secondary properties (second order) requiring additional perceptual processing [11]. To process the second-order tasks, more brain regions must be activated [12,13]. The stimulation can be defined as more complex if it needs to process one or more properties in perceiving the image.

Recognizing visual information has a hierarchical structure. Sensory information is stored in the working memory and is compared with the previously stored information when it moves to a perceptual processing stage at a different level, and is detected. Various processing functions and stages, such as the sensory processing function of visual perception, the perceptual processing function, and the working memory function, must be activated organically to make a decision based on a single image [14,15]. Previous studies proved that the working memory function deteriorates with age [16]. According to Habak and Faubert [17], aging affects the perception of stimulation that requires more complex cortical processing when the first-order or luminance-defined stimulation and the second-order or texture-defined stimulation are compared. In other words, more processing is required when the complexity of the objects included in the stimulation increases, and functional defects may appear in the cognitive processing in these complex stages as aging progresses [18].

2.3. Image quality and memory color

In a study by Tremeau and Charrier [19], it was explained that the relationship between image color and image quality and between colorfulness and naturalness act as major factors in evaluating image quality. When the colorfulness of an image is adjusted according to the memory color at a similar level, the naturalness of the image increases and positively affects the image quality evaluation. As explained, the color reproduction and image quality preference of an image are closely related to memory color. Memory color tends to appear with higher brightness and saturation than the actual color [20–22]. In particular, the main feature of memory color is that its chroma/saturation is higher than that of the actual color [23,24]. Previous studies showed that the image quality preference increased when the saturation was adjusted to make it close to the memory color [25,26]. Especially, as the saturation increased to the level similar to the memory color, the tendency of image quality preference increased [27]. This characteristic of memory color was also manifested in the same manner on the display medium that reproduces color with light in an experiment conducted with an RGB monitor by Olkkonen et al. [28].
3. Method

3.1. Stimulation and test environment

Images with a 1920 × 1080 resolution were collected for subjective image quality evaluation. Artificial graphic images have higher saturation than images of natural objects. This study used both natural images and artificial graphic images when constructing the test images. Also, as whether or not there is an object to be noticed and the distance between the object and the camera in the images affect the image quality evaluation [29], image stimuli were carefully selected to reduce the influence of the image content characteristics on the subjective image quality evaluation. Accordingly, four test images were derived for subjective image quality evaluation.

The brightness and saturation of the test images were adjusted with Adobe Photoshop CS6. The changes in the adjusting step (%) compared with the original image were derived by applying the JND (just-noticeable difference) experiment method. The JND experiment in this study was conducted for nine days, from 1 to 9 June 2015, and the subjects consisted of 15 female color experts in their 20s and 30s. The contrast stimuli method was applied. That is, the subjects were shown the original image, followed by the image with adjusted brightness and saturation among the perceptive properties of image quality, and were asked to say ‘Same’ if they felt that the two images were the same, and ‘Different’ if they felt they were different. The point at which the ratio of subjects who said that all the four images (the test images used in the JND experiment: N1, N2, AG1, and AG2) were ‘different’ was over 50% was regarded as the minimum discrimination point. As a result, for brightness, the subjects noticed a difference between steps +10 and +13 and steps −13 and −17 in the brightness change adjusted with Adobe Photoshop CS6. For the change in the saturation value, the subjects noticed a difference between steps +5 and +10 and steps −10 and −17. The brightness and saturation adjustment steps using the JND test results were increased to three increase steps and three decrease steps. The adjustment value (%) represented as the increase/decrease ratio with respect to the original is shown in Table 1. As shown in Table 2, the brightness and saturation levels of the four test images were adjusted.

For the test environment, the illumination was adjusted to 300 lx by referring to the Korean Industrial Standards (KS) indoor illumination range. For the monitor, which was the output device, a 27-inch DreamColor z27x Professional Display by HP was used. Figure 1 shows the tone reproduction curve (TRC) of the monitor. The luminance of white was 224.7 cd/m².

### Table 1. Rendering values (%) of color attributes.

| Brightness |
|------------|
| Increase | Decrease | Increase | Decrease |
| 5%  | 8%   | 6%  | 10%  |
| 9%  | 10%  | 15% | 14%  |
| 13% | 12%  | 28% | 19%  |

### Table 2. Stimuli for the subjective image quality experiment.
3.2. Evaluation items for the subjective image quality experiment

Engeldrum [30] mentioned the customer perceptions the ‘ness’ among the important factors of image quality evaluation in ‘Adapted Image Quality Circle,’ which is an image quality evaluation model. In other words, the evaluation vocabularies that represent these cognitive attributes should be used in the image quality evaluation because images are accepted through visual and emotional cognitive properties as people are unfamiliar with the technical terms for image quality. Radum et al. [31] derived the factors that influence the subjective preference of photography, and ‘bright/sunny,’ ‘not sharp,’ ‘artistic,’ ‘real,’ ‘not shiny/dirty/not fresh,’ ‘sharp,’ and ‘shiny/clean/fresh’ were derived as the factors that have immense influence on the image quality preference with 0.7 or higher Kappa coefficients. Based on these previous researches, a total of nine adjectives such as ‘bright,’ ‘clean,’ ‘natural,’ ‘soft,’ ‘familiar,’ ‘sharp,’ ‘colorful,’ ‘realistic,’ and ‘image quality is good’ were selected as the evaluation vocabularies for the subjective image quality evaluation test.

3.3. Demographic characteristics of the study subjects, and test methods

Demographically, 41 subjects in their 20s and 30s were placed in the adult group and 30 subjects aged 55 and over were placed in the elderly group (Figure 2). The average age of Adult group was 27.13 and the average age of elderly group was 61.93. As eye fatigue is manifested more quickly in the elderly group than in the adult group when watching the display, the same experiment was divided into two sets in which the subjects in the adult group underwent both sets, while the subjects in the elderly group underwent only one set at a time. One set of experiments took about 30 min to finish. The distance between the subject and monitor was fixed at 50 cm, and all images were presented randomly to the subjects. The subjects were asked to respond based on a 7-point Likert scale by marking from 1 point to 7 points for each of the nine adjectives that are the image quality evaluation items.

4. Results and discussion

4.1. Results of the analysis of the evaluation items affecting image quality preference

4.1.1. Results of the analysis of the evaluation item factors

Factorial analysis was performed to determine the validity and reliability of the evaluation words that were used in the subjective image quality evaluation test (Table 3). The factorial analysis results showed that the Cronbach’s alpha value was greater than 0.8 (0.891), which indicated that the reliability of the questionnaire on subjective
Participants in the subjective image quality evaluation experiment were divided into two main factors. The first factor, which includes the four evaluation words ‘familiar,’ ‘natural,’ ‘soft,’ and ‘realistic,’ requires a comparison with the existing memory beyond the simple cognitive domains. As it requires the subject’s subjective cognitive processing, it was named the ‘subjective’ factor. The four evaluation words ‘sharp,’ ‘colorful,’ ‘clean,’ and ‘bright’ (excluding ‘image quality is good’) do not require a comparison with the existing memory and can be determined instantly after seeing the corresponding image. They were determined to have less intervention by the subject’s subjective cognitive processing and were thus collectively named ‘objective’ factor.

4.1.2. Results of the multiple regression analysis of the evaluation items

The multiple regression analysis of the elderly group showed that the explanatory power of the model appeared at around 87% \((\text{adj} R^2 = 0.869)\), and that the residual independence \((\text{Durbin–Watson} = 2.159)\) was satisfied (Table 4). ANOVA showed that the significance probability for the \(F\) value \((F = 68.318)\) was appropriate \((p < .001)\), and that the regression model was appropriate. The regression coefficient analysis showed that the two variables ‘clean’ \((\beta = .360; p < .05)\) and ‘sharp’ \((\beta = .584; p < .001)\) had a significant impact on the dependent variable. Both independent variables had positive effects on the dependent variables. It was confirmed that the elderly group was affected by the degree of cleanliness and clarity when evaluating the image quality. Particularly, the \(\beta\)’ value of ‘sharp’ appeared to be very large, and it can thus be said that the degree of sharpness of the image has a greater influence when judging the image quality.

The multiple regression analysis results of the adult group showed that the explanatory power of the model
Table 4. Results of the multiple regression analysis for the elderly group.

| Dependent variable | Independent variable | B   | \( \beta \) | t    | p     | VIF |
|--------------------|----------------------|-----|-------------|------|-------|-----|
| Image quality      | (Constant)           | .630| –           | –    | .046  | –   |
|                    | Bright               | −1.125| −.161      | −1.409| .163  | 8.074|
|                    | Clean                | −3.316| 3.600      | 2.320| .023* | 14.916|
|                    | Natural              | −.115| −.111      | −0.839| .404  | 10.924|
|                    | Soft                 | .016 | .017       | 0.148| .883  | 8.133|
|                    | Familiar             | .205 | .201       | 1.537| .129  | 10.549|
|                    | Sharp                | −.500| .584       | 4.098| .000***| 12.600|
|                    | Colorful             | .078 | .091       | 1.023| .310  | 4.933|
|                    | Realistic            | .049 | .036       | 0.347| .730  | 6.739|

Note: \( R^2 = 0.882, (adj) R^2 = 0.869. \)
* \( p < .05. \)
*** \( p < .001. \)

Table 5. Results of the multiple regression analysis for the adult group.

| Dependent variable | Independent variable | B   | \( \beta \) | t    | p     | VIF |
|--------------------|----------------------|-----|-------------|------|-------|-----|
| Image quality      | (Constant)           | −.319| –           | −1.286| .202  | –   |
|                    | Bright               | −.127| −.157      | −2.027| .046* | 14.200|
|                    | Clean                | .043 | .044       | 0.382| .703  | 31.289|
|                    | Natural              | .096 | .082       | 0.914| .364  | 18.813|
|                    | Soft                 | .088 | .074       | 1.303| .197  | 7.723|
|                    | Familiar             | −.048| −.038      | −0.417| .678  | 20.126|
|                    | Sharp                | .719 | .859       | 9.128| .000***| 20.923|
|                    | Colorful             | .108 | .156       | 1.812| .074  | 17.560|
|                    | Realistic            | .246 | .152       | 2.882| .005* | 6.590|

Note: \( R^2 = 0.969, (adj) R^2 = 0.966. \)
* \( p < .05. \)
*** \( p < .001. \)

was 97% \((adj) R^2 = 0.966\) and that the residual independence (Durbin–Watson = 2.159) was satisfied (Table 5). The ANOVA results showed that the significance probability for the F value \( F = 286.280 \) was appropriate \((p < .001)\), and that the regression model was also appropriate. The results of the regression coefficient analysis showed that the three variables ‘bright’ \((\beta = −.157; p < .05)\), ‘sharp’ \((\beta = .859; p < .001)\), and ‘realistic’ \((\beta = .152; p < .05)\) had a significant effect on the dependent variables. Among the three independent variables, ‘sharp’ and ‘realistic’ had a positive effect on the dependent variables, and ‘bright’ had a negative effect. This indicated that the adult group was affected by the degree of sharpness, and that the degree to which the image was perceived to be realistic had a great impact on the adult group when evaluating the image quality. Particularly, the \( \beta \) value of ‘sharp’ appeared to be very large, and it can thus be said that the degree of sharpness of the image has a greater influence when judging the image quality. On the other hand, it was confirmed that the image quality could, in turn, worsen when the image is perceived as brighter.

The multiple regression analysis results showed that there were differences in the evaluation items affecting the image quality evaluation between the adult and elderly groups. In the elderly group, the evaluation items ‘clean’ and ‘sharp’ had positive influences on the image quality evaluation, while in the adult group, it was the evaluation items ‘sharp’ and ‘realistic’ that had positive influences on the same. For the evaluation item ‘sharp,’ the \( \beta \) value was larger in the adult group, and this confirmed that the adult group was affected more by the sharpness of the image. The elderly group evaluated the image that was seen as sharper and clearer as having good image quality, and the adult group evaluated the image that they saw as clearer and realistic as having good image quality. The evaluation item that showed a negative effect in the image quality evaluation was ‘bright,’ and its influence appeared only in the adult group. This confirmed that the adult group could evaluate the image quality as being poor when the brightness of the image increases. On the other hand, how bright the image appeared to the elderly group did not have a significant impact on the quality of the image.

It is noteworthy that the evaluation item other than ‘sharp’ that affected the image quality was different in the two age groups: ‘clean’ and ‘realistic,’ respectively. As a result of the previous factorial analysis, ‘clean’ and ‘sharp’ belong to the ‘objective’ factor, and ‘realistic’ belongs to the ‘subjective’ factor. The evaluation items belonging to the ‘objective’ factor (‘sharp,’ ‘colorful,’ ‘clean,’ and ‘bright’) have more intuitive properties than the evaluation items belonging to the ‘subjective’ factor (‘familiar,’ ‘natural,’ ‘soft,’ and ‘realistic’). The evaluation items...
belonging to the ‘subjective’ factor require more perceptual and cognitive processes because they need comparison with previous memories. The fact that the evaluation items affecting the elderly group’s image quality evaluation consist only of ‘objective’ factors can be explained in this context. Zacks and Hasher [32] added reduced processing resources, deteriorated processing capacity, and increased difficulty in prohibiting irrelevant information to the factors that explain the reduction of the working memory due to aging. In other words, the evaluation items such as ‘familiar,’ ‘natural,’ and ‘realistic,’ which require complex processing (e.g. perception, recognition, and comparison with previous memories), may not have worked properly in the elderly group. The stimulation images in this study consisted of images with various cognitive properties, such as images with various colors, images with or without objects, and images with near or far vanishing points, to neutralize the influence of the image’s characteristics on the image quality. In other words, the stimulation images in this study included luminance and color in the first order and texture and depth information in the second order, according to the image’s cognitive properties defined by Marr et al. [10].

Carrying out subjective image quality evaluation using nine evaluation words while seeing the stimulation images with various cognitive properties involves complex visual perception and cognitive structure. According to the research results of Faubert [18], who discovered that functional defects may appear in the cognitive process through these complex stages as aging continues, the elderly group may have some errors in a number of cognitive stages in which they need to perform subjective image quality evaluation. It is possible to deem that the difference in the evaluation items influencing the image quality evaluation between the two age groups may have resulted from this discomfort of the elderly group.

4.2. Results of the analysis of image quality preference according to the changes in brightness and saturation

The analysis was performed by normalizing the response to ‘good image quality’ among the subjective image quality evaluation items into a value between 0 and 1. According to the subjective image quality evaluation, the image quality preference appeared differently for each age group when the brightness and saturation of the images were changed.

First, as shown in Figure 3, the change in the image’s brightness showed a difference between the two age groups in the decreasing direction of change than in the increasing direction. The elderly group responded less sensitively than the adult group when the brightness of the image decreased. When the brightness of the image was reduced by 8%, the image quality preference value of the adult group decreased by about 7%, but the elderly group retained the image quality preference value of the original image. On the other hand, the image quality preference values of the adult and elderly groups were similar in the images where the brightness decreased by 12%. These results showed that the elderly group did not recognize the difference when the brightness of the image was slightly reduced, but they could recognize the difference in brightness when the brightness of the image was increased.

![Image Quality Preference vs. Brightness](image.png)

**Figure 3.** Degree of image quality preference per brightness adjustment (with standard error).
was greatly reduced, similar to the level by which the adult group could. This may be attributed to the elderly people’s visual perception characteristics, reduced luminosity due to aging, and macular degeneration of visual organs. For the subjects in the elderly group, the transparency of their crystalline lens is deteriorated due to aging, rendering them unable to recognize the saturation and brightness of colors, which the subjects in the adult group could [7]. Also, the ability to perceive brightness and darkness declines as the number of rods decrease with age [2]. The reason that the elderly group is less sensitive to the decrease in the brightness of the image could be the dimming of their contrast sensitivity due to aging. In other words, when the brightness of the image decreases, the elderly group may perceive the rate of reduction in brightness as less than the actual because the ability to perceive contrast deteriorates due to aging, and it has been confirmed that this phenomenon has a huge influence on the image quality preference.

Both the adult and elderly groups in this study chose high image quality evaluation points when the brightness of the image increased. Particularly in the elderly group, the subjects gave similar points as the image quality evaluation points for the original image, without a declining tendency in the image quality evaluation points even when the brightness increment became very large (brightness +13%). This is also consistent with the results of previous studies [2] that showed deterioration of the ability to perceive contrast with age. The elderly group does not notice the increase in brightness as much as the adult group does due to the deterioration of the former’s ability to perceive contrast, and the increase in brightness even above a certain rate (+13%) did not negatively affect the elderly group’s image quality evaluation. In other words, it was confirmed that keeping the brightness of the image above the ordinary level is important in yielding a positive influence on the image quality preference for the elderly group.

Like the change in brightness, a change in saturation resulted in a greater difference between the adult and elderly groups in this study, in the decreasing direction (Figure 4). The image quality preference of the elderly group was only slightly affected by the reduction of the image’s saturation (−11%), whereas the image quality preference of the adult group decreased substantially (−30%) as the saturation of the image decreased. These results can be explained by the characteristics of the visual organ of elderly people, which includes difficulty in recognizing the difference at the same brightness level due to the degeneration of their crystalline lens [7]. In other words, the elderly group may not be able to visually recognize a decrease in the saturation of an image.

The image quality preference of the adult group slightly increased (+4%) when the saturation increased, but that of the elderly group was not much influenced by the change in saturation. This is quite different from the outcomes of previous researches [25,26] that reported that the saturation of an image substantially affects the image quality preference, and that a higher image quality preference was found in the images with elevated saturation, like the memory color. This shows the need for studies on image quality preference reflecting the visual characteristics of the elderly group.
5. Conclusion

As a result of the subjective image quality evaluation conducted with subjects divided into the two age groups of adult and elderly groups, two significant differences were confirmed. First, the types of evaluation items that were shown to affect the image quality evaluation were different in the two age groups. In the elderly group, the evaluation items ‘sharp’ and ‘clean’ influenced the image quality evaluation whereas, in the adult group, it was the evaluation items ‘sharp,’ ‘bright,’ and ‘realistic’ that affected the image quality evaluation. In the adult group, the evaluation items that require a more complex cognitive process such as comparison with past memories affected the image quality preference. Meanwhile, in the elderly group, the evaluation items relating to simple cognitive domains, such as whether the image is seen more sharply and clearly, affected the image quality evaluation. These results show that the elderly group evaluates image quality through simpler perceptual and cognitive processes compared with the adult group. Second, the two groups showed a difference in image quality preference tendencies according to the changes in the brightness and saturation of the image. The image quality preference tendency of the elderly group was not significantly affected by the decrease and increase of the brightness and saturation. Remarkably, the elderly group’s image quality preference value remained high even when the brightness of the image increased sharply. Also, the image quality preference tendency of the elderly group according to the change in saturation is in conflict with the result of the image quality preference study based on the existing memory color. Therefore, an image quality design considering the elderly group’s visual sensibility and cognitive ability is needed. These results show that the change in saturation does not have a significant impact on the image quality preference of the elderly group, and that to keep the image quality preference of the elderly group at a high level, it is necessary to increase the brightness of the image.

Disclosure statement

No potential conflict of interest was reported by the authors.

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