Designing a User Interface for a Painting Application Supporting Real Watercolor Painting Processes

Jiho Yeom
Graduate School of Culture Technology, KAIST
335 Gwahangno, Yuseong-gu,
Daejeon 305-701, Korea
Jiho6493@kaist.ac.kr

Geehyuk Lee
HCI Lab, KAIST
335 Gwahangno, Yuseong-gu,
Daejeon 305-701, Korea
geehyuk@gmail.com

ABSTRACT
While research on non-photorealistic rendering is providing simulation-based realistic watercolor painting effects, the current digital painting interfaces are yet to be improved for providing realistic watercolor painting experience. This study proposes a digital watercolor painting interface to support real watercolor painting processes. We evaluated the new interface in comparison with a conventional digital watercolor painting interface with respect to effectiveness, efficiency, and satisfaction. The new interface was not different in terms of efficiency, but was shown to be more effective in that it enabled the users produce more satisfactory paintings than the conventional interface. It was also favored in terms of satisfaction. This result suggests that a user interface supporting real watercolor painting processes is important for the usability of a simulation-based digital watercolor painting system.

Author Keywords
Digital Painting; Interface Design.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces. – Interaction styles; I.1.34 [Computer Graphics]: Graphics Utilities.–Paint systems.

General Terms
Human Factors; Experimentation; Design.

INTRODUCTION
Digital painting systems have evolved greatly over the past few decades. In particular, research on non-photorealistic rendering is providing simulation-based realistic watercolor painting effects [8, 21]. However, existing digital painting interfaces are not suitable for providing realistic watercolor painting experience. Some studies pointed out that the conventional digital painting systems are so sterile that they only took a shallow view of the processes of real painting [4, 5]. For example, painters iteratively change the properties of the painting brush with watercolor painting tools, but the conventional digital painting interfaces do not support this kind of real watercolor painting processes.

APCHI '12, August 28–31, 2012, Matsue-city, Shimane, Japan.

The following three requirements are essential for a digital painting system to support realistic watercolor painting experience. First, it should provide a direct manipulation environment. Some digital painting systems use a graphics tablet, thereby providing an indirect manipulation environment. This can cause an eye-hand coordination problem. A direct manipulation environment will be essential for users to have realistic painting experience. Second, the basic properties of real painting tools should be respected. For example, a brush is flexible, dynamic, and area-based tool. A graphics tablet pen, on the other hand, is a hard-pointed and point-based input device. The use of a brush-like input device will enable users experience more realistic digital watercolor painting. Finally, real painting processes has to be respected. Existing digital painting systems usually provide slide bars and select boxes for controlling painting parameters such as color and brightness. Users in this case adjust painting parameters individually with the slide bars and the select boxes. However, in real watercolor painting, the adjustment of the painting parameters is done using painting tools, such as a brush and water, and more than one painting parameters are usually controlled together. For example, a user controls the wetness and the intensity of a brush at the same time by adding water.

Among these three requirements, the first two have been considered often in early studies pursuing realistic digital painting experience. For example, there are studies proposing a direct-manipulation, digital painting environment with a real brush or a brush-like device [12, 14, 17, 22, 23]. On the other hand, the third requirement has rarely been considered, i.e., no studies so far paid a serious attention to the requirement of a digital painting environment supporting the processes of real watercolor painting. In fact, there are some studies paying attention to the processes of real oil painting, but oil painting processes are different from watercolor painting processes.

In the study presented in this paper, we investigated real watercolor painting processes, and designed a digital watercolor painting interface with real watercolor painting tools to support real watercolor painting processes. We

evaluated the usability of the new interface in comparison with a conventional digital watercolor interface.

RELATED WORK

There have been a number of studies suggesting solutions for the usability problem of using a tablet stylus and for bridging the real painting and the digital painting. CoolPaint, IntuPaint, and MAI Paint Brush proposed digital painting systems that use a brush-like device in a direct manipulation environment like a tabletop environment or a mixed-reality environment [12, 14, 22]. Digital Canvas and FluidPaint suggested digital painting systems that use a real painting brush [17, 23].

There are also studies proposing a user interface with painting tools [3, 4, 19]. HabilisDraw proposed a tool-based drawing interface, and showed that a tool-based approach has some advantages in terms of intuitiveness and ease of use [19]. Baxter's works suggested an immersive painting environment mimicking a real painting environment [3, 4]. By the way, the proposed interfaces by these studies cannot be applied to our case because their target domains were different from watercolor painting. However, these studies support our expectation that bringing the tools of real watercolor painting into a digital painting interface may have possible advantages.

In our study, we adopted a tabletop interface using a real brush from early works to handle the problems of an indirect manipulation environment and a graphics tablet. On top of the existing platform, we propose a user interface with real watercolor painting tools to support real watercolor painting processes.

WATER-COLOR PAINTING

Watercolor Painting Processes

Watercolor painting consists of two steps as shown in Figure 1: sketching and painting. Sketching is a process independent of watercolor painting, which is done before watercolor painting. Painting consists of two steps: adjustment of brush properties and stroke. To adjust brush properties, a user adjusts the color, its intensity, and wetness of the brush. Stroke is a step that makes a footprint of the brush on the canvas. These two steps are iteratively done during the watercolor painting process.

Adjustment of brush properties

This step is adjusting brush properties for intended watercolor effects. It consists of adjusting the color, intensity of the color, and wetness of the brush. Adjusting the color can be either by selecting an existing color on a palette or by mixing more than two colors. Adjustment of brush properties may or may not be required depending on the situation. Adjusting brush properties is done iteratively with watercolor painting tools.

Stroke

Stroke is a major activity in watercolor painting, making a footprint of the brush on the canvas. Various watercolor effects may be possible depending on the brush properties.

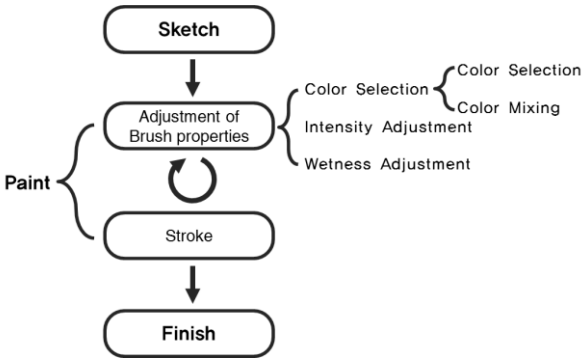

Figure 1. Watercolor painting processes

Watercolor Painting Tools

Brush

In real watercolor painting, brush footprints are created on the touched area of the canvas. The brush is used for adjusting brush properties with water, a towel, and a palette. Various kinds of watercolor effects like dry-brush, edge darkening, back-runs, granulation, and flow patterns are created by adjusting the wetness and the color intensity of the brush. In addition, a brush tip shows the current value of brush properties. As the tip of the brush shows the brush shape and color, a painter can predict the thickness and the color of a stroke. Also, a painter can guess the approximate value of the intensity and the wetness of the brush through the tip of the brush.

Watercolor paints and palette

Watercolor paint determines color, and the amount of the watercolor paint on the brush determines the intensity of the color. A palette is used to keep watercolor paints, and to mix them to create a new color.

Water and towel

Water is one of the most important materials in watercolor painting. A user rinses the brush with the water, increasing the wetness of the brush. At the same time, this decreases the intensity of the color. Various watercolor effects are possible depending on the wetness of the brush. A towel is used to dry the brush after rinsing. The function of a towel is to decrease the wetness of the brush.

Basic Skills of Watercolor Painting

There are various watercolor painting techniques in watercolor painting. In the following, we define six basic skills of watercolor painting: Flat Wash, Graded Wash, Glazed Wash, Wet-In-Wet. Dry Brush, and Lifting.

Flat Wash is the most basic skill, which is painting the area with a consistent intensity of the color and wetness. It does not need any adjustment of the brush properties in digital painting. **Graded Wash** is painting the area gradually by changing the brush properties. This skill is often used to express the background such as the sky. **Glazed Wash** is creating a glazed effect, adding thin watercolor layers on a dried layer. **Wet-In-Wet** adding layers of wet paint on a wet canvas. Accidental effect of watercolor is shown by the flow of water. **Dry Brush** is painting with little wetness. It is mostly used to express rough textures, applying paint only to the raised areas of the paper [8]. **Lifting** is removing the layers of watercolor with a clean brush. It can be easily done when the layer is wet, and the lifted area will be lightened. This skill is used not only to remove the painted area but also to express light and pale effects like clouds.

Figure 2. 6 basic skills of watercolor painting

PAINTING APPLICATION PROTOTYPE

We made a prototype supporting real watercolor painting process. The prototype has tools that resemble the look, use and function of real watercolor painting tools.

System

The prototype is developed for a tabletop environment. The tabletop detects a blob of a touched area of the brush, and creates the footprint of the brush based on the information of the position and the size of the blob. The tabletop is of Rear-DI (diffused illumination) type [20], and has the dimension of 102cm x 79cm x 80cm. The camera in the tabletop had the resolution of 640 x 480 pixels and the frame rate of 22 FPS and was equipped with an infrared passing filter. The tabletop uses a projector of 2,200 ANSI lumens.

To detect the touched area of the brush, the prototype used Community Core Vision (CCV) which was customized to send TUIO 2D blob messages [7]. CCV detects and sends the position, the orientation, and the width and height of the touched area of the brush. In addition, WetDream was used to simulate realistic watercolor effect. WetDream is an open source semi-realistic watercolor simulation tool made by Raph Levien [13]. It produces watercolor effects by a flow simulation with watercolor brush properties in real-time, and can be used for an interactive digital watercolor painting system. The prototype ran on a desktop PC with a 3.2 GHz dual-core CPU and 2GB RAM.

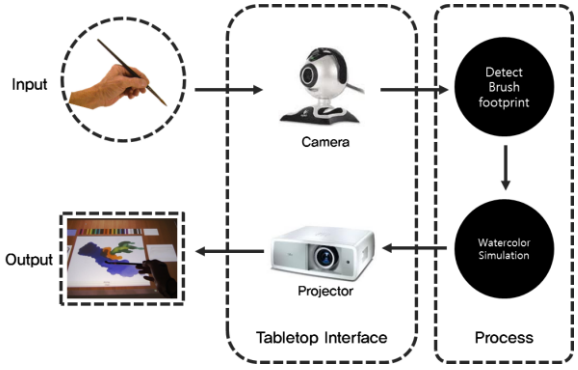

Figure 3. The structure of the painting application prototype

User Interface

We made a user interface for digital watercolor painting as shown in Figure 4. It consists of a canvas, a palette, water, a towel, a dashboard, and a test board.

Figure 4. The user interface of the painting application prototype

Canvas

The 500 x 500 pixels canvas is in the center of the screen, and generates the footprints of the brush as an ellipse according to the information of the touched area. Footprints generated on the canvas are different depending on the brush properties as shown in Figure 5. When the brush is wet, the brush stroke has white diagonal lines on it. These lines gradually disappear as the stroke dries. The stroke with a low wetness displays a Dry Brush effect, applying paint only on the raised areas of the paper.

Figure 5. The stroke on the canvas

Palette

A palette is placed above the canvas. It has three gray scale colors, pure water, and eleven colors introduced in Curits' work: Quinacridone Rose, Indian Red, Cadmium Yellow, Hookers Green, Cerulean Blue, Burnt Umber, Cadmium Red, Brilliant Orange, Hansa Yellow, Phthalo Green, and French Ultramarine [8]. Since every watercolor paint is transparent except opaque white, a blended color appears when the user dubs multiple colors on the canvas except opaque white. Opaque white is used for erasing or highlighting. As one of the three grayscale colors is opaque, the three grayscale colors are shown with black background and white background together so that the user can distinguish an opaque color. The palette has pure water on the rightmost cell to reset the brush to a transparent state immediately without using water for convenience. The palette is used to load watercolor paint, increasing intensity of the color. As a user rubs paint on the palette, the intensity of the selected color increases as shown in Figure 6.

Figure 6. The function of the palette

The palette is also for mixing colors like in real watercolor painting. When a user rubs on paint on the palette, the color of the brush will be mixed with the paint color gradually. For example, when the current color is yellow and a user rubs on blue paint, the color of the brush becomes green. When the user rubs on blue paint again, the color turns blue. As all colors except opaque white are transparent, mixing with the opaque white and pure water is not allowed. When a user rubs on opaque white or on pure water, the color of the brush immediately changes to the selected color.

Water

The water is an image of water contained in a transparent glass, placed on the left side of the canvas. The function of the water is to decrease the intensity of the color and increase the wetness of the brush at the same time as shown in Figure 7. A user can dilute the paint by varying the rubbing speed on the glass of water on the screen as in real watercolor painting. When the user continuously rubs the water on the screen, the intensity of the color becomes zero, and then the color of the brush becomes transparent just like pure water. This act can be compared to rinsing the brush in real watercolor painting.

Figure 7. The function of the water

Towel

A towel is located on the right side of the canvas. The function of the towel is to decrease the wetness of the brush. When the user rubs on the towel on the screen, wetness of the brush decreases depending on the number of rubbing as shown in Figure 8.

Figure 8. The function of the towel

Dashboard

A dashboard is on the right side of the canvas, presenting the current status of the brush properties which cannot be shown on the brush tip in digital painting. As shown in Figure 9, the color of the brush is shown with black background. Also, the wetness and the intensity of the color are shown by the slide bars without numeric value. The slide bars are only for a display purpose and cannot be adjusted. As in real watercolor painting, the wetness and the intensity of the color are not presented precisely, letting the user guess the approximate levels of the wetness and the intensity from the slide bars.

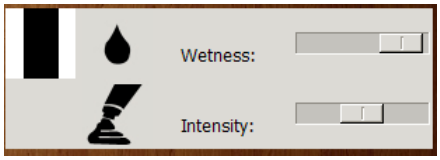

Figure 9. The dashboard showing the brush state

Test board

A test board is on the right side of the canvas. A user can test his or her brush strokes on the test board before making strokes on the canvas. The stroke on the test board disappears as time goes. The test board may not be needed when an undo function is implemented later.

EVALUATION OF THE USER INTERFACE

We did an experiment to compare the usability and the advantages of the interface that we designed with that of a conventional digital watercolor painting interface.

Apparatus

The experiment was conducted with the two painting interfaces shown in Figure 10 on the same tabletop. Interface A is the digital watercolor painting interface introduced in the prototype section, and Interface B imitates a conventional digital painting interfaces. It has slide bars for controlling the wetness and the intensity of the color independently. Also, the values of the brush properties are presented with numeric values on the slide bars. The palette of the interface B is not for adjusting the intensity of the color, but is only for selecting a color. Also, it does not support mixing colors, and therefore a color picker was

offered. The color picker enabled the user select an exact color that a user wants. The size of the canvas, color representation, and watercolor simulation are the same as Interface A. Also, both interfaces were run on the same hardware environment described in the prototype section. Two round brushes were used in the experiment: number 15 round and number 20 round. Participants could change between the two brushes freely while they were painting.

Participants

Twelve volunteers (9 females, between 21 and 32 years old) participated. All participants were familiar with watercolor painting and had knowledge about watercolor painting tool usage, but not all participants were familiar with digital painting. Six participants were familiar with digital painting. One of the participants was an active physical painter, and another majored in pure painting. Two other participants majored in industrial design.

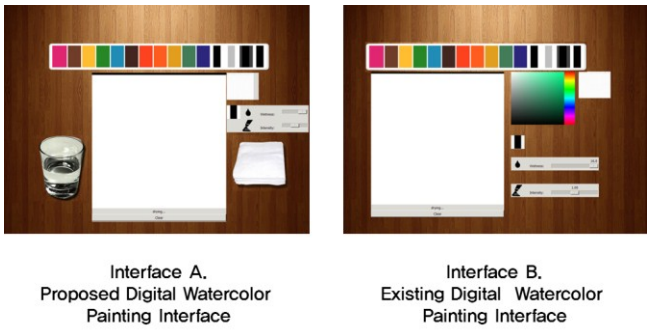

Figure 10. Experimental setup

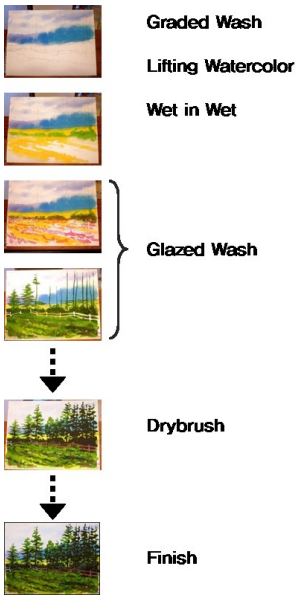

Figure 11. Tutorial painting task and the basic skill of watercolor painting corresponding to each step

Figure 12. Task performing participant

Tasks

The experiment consisted of two tasks: tutorial painting and free painting. Tutorial painting included an instruction to complete each painting. We used a tutorial from Watercolorpainting.com, about the six basic skills of watercolor painting [24]. In the tutorial painting task, the pictures for each step were given, and the description of the step was given in natural language without the name of the skills. The skill required for each step is illustrated in Figure 11. A picture of a participant performing a tutorial task is shown in Figure 12. In free painting tasks, participants were asked to paint an apple freely. The photograph of an apple was given. The participants could paint in however they wanted. Samples paintings from the experiment are shown in Figure 13.

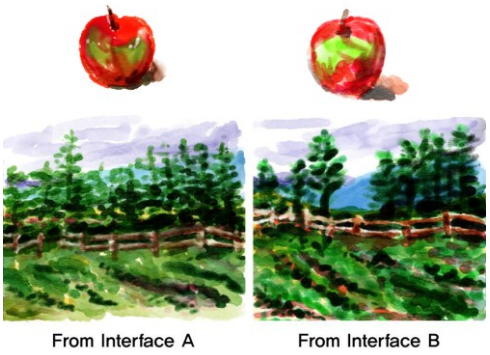

Figure 13. Samples from the experiment

Procedure

The subjects participated in the experiment after a brief introduction of the two interfaces. Before the experiment, they were asked to go over the six basic skills on both interfaces. The test session lasted about an hour and a half per each participant. It included a brief introduction session of the two interfaces and exercise of the six basic watercolor skills. Participants were divided into two groups, and each group started with a different interface. Every participant did a free painting task after the tutorial painting task. Participants were asked to paint naturally as usual. After each task, we asked the participants to fill out a user questionnaire with 7-step in Likert scale and had a short debrief session.

Measures

To evaluate the usability of the two interfaces, we measured the effectiveness, efficiency, and participants' satisfaction level of the interfaces. Effectiveness of the digital watercolor painting system is closely related to how much the user can make an aesthetically satisfactory work. To measure the effectiveness, we asked the users to rate the aesthetic satisfaction of his or her work done with each interface. To measure the efficiency, total time spent of painting and the time spent for 6 watercolor painting skills were measured. To measure the participants' satisfaction level, questionnaire for the interfaces was used. It included the questionnaire of the perceived usefulness, perceived ease of use, and preference of the system.

Besides measuring these aspects, the user's overall feelings about the experiment were measured by using a self-report questionnaire with the scale developed by Jeong. [11] It consists of 6 categories: Aesthetics, Satisfaction in Usability, Novelty, Uncomfortableness, Pleasure, and Excellence. Aesthetic is a positive emotion expressed due to various visual information of the system. Satisfaction in Usability is the positive emotion due to usability or practical aspect of the system. Novelty is the positive emotion expressed due to originality of the system. Uncomfortableness is uncomfortable or unpleasant feeling while using the system. Excellence is a positive emotion expressed due to outstanding aspects of the system. Each question is presented with related adjectives extracted by Jeong for convenience.

RESULTS AND DISCUSSION

Effectiveness

Satisfaction of the work

An average score of the satisfaction of the work done by each interface is shown in Figure 14A. The average score of participants' satisfaction about their work with the interface A was higher than that of the interface B significantly (paired samples t-Test, p = 0.001). The participants could make aesthetically more satisfactory work with proposed interface. More than half of the participants indicated that they felt like they painted with real painting tools and used watercolor painting skills more naturally. They also indicated that the watercolor effects were well expressed in the paintings from the interface A rather than the interface B. It seems that the participants could make use of their experience of real watercolor painting process with the interface A, and it helped them make more satisfactory work.

In addition, a blind evaluation was performed on aesthetic satisfaction of work with people who did not participate in the experiment. We recruited 38 participants (16 males, 22 females), 20-30 years old, from online community related to painting. We showed paintings from two interfaces from same person without telling anything, and asked to choose more aesthetically satisfying one. The result of the blind evaluation is shown in Figure 14B. The paintings from the interface A were preferred by viewers with significant difference (paired samples t-Test, p = 0.0). The paintings from the proposed interface were aesthetically more satisfactory.

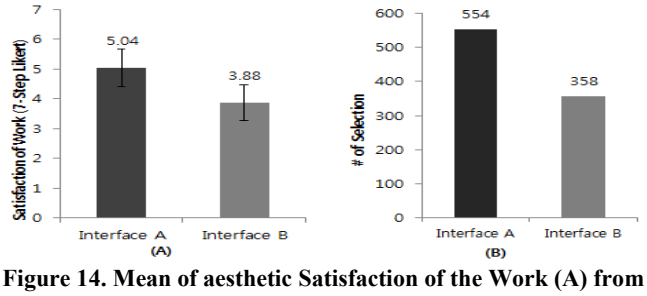

Figure 14. Mean of aesthetic Satisfaction of the Work (A) from participants (B) from blind evaluation

Efficiency

We measured the total time spent and time spent for 6 basic watercolor painting skills during the tutorial painting task. In the tutorial, each step represented a different watercolor skill. We did not measure the time spent for the flat wash because it is a simple skill without adjusting the brush properties so there was no difference between the two interfaces.

The total time spent in the interface B was shorter than that of the interface A. From this we know that the participants did painting quickly with existing interface, but it has no significant difference (paired samples T-test, p=0.174). In addition, the participants took less time in using Lifting Watercolor under the interface A than the interface B with a significant difference (paired samples T-test, p=0.017). Other skills had no significant differences between the two interfaces. Compared to the interface B, the user could not easily get the precise brush property values with the interface A, so the participants might need more activities to get the brush property values they want with the interface A. However, it was not that significant difference. Consequently, we can say that there was no significant difference in efficiency between the two interfaces.

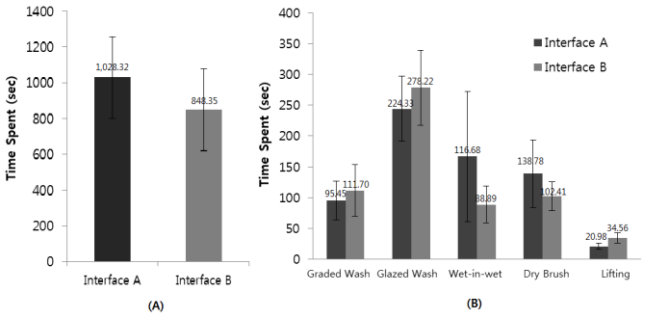

Figure 15. Mean time spent on tutorial painting: (A) total time (B) time for each of the basic skills of watercolor painting

Satisfaction

Perceived Usefulness and Perceived Ease of Use

Perceived usefulness shows how a user thinks the interface is useful, and perceived ease of use can show the easiness of the interface user thinks.

Perceived usefulness and perceived ease of use of the two interfaces are shown in Figure 16. The result of the perceived usefulness was higher in the interface A than in the interface B, but it had no significant difference (paired samples T-test, p=0.067). However, the perceived ease of use of the interface A was higher than that of the interface B with significant difference (paired samples T-test, p=0.0). The usefulness perceived by the participants was different by individual participants. Some participants accustomed with conventional digital painting interface indicated that the interface B was effective, but the opposite case indicated that the interface A was effective. However, every participant agreed that the interface A was easy. We can say that the proposed interface is easier to use than the existing digital watercolor painting interface.

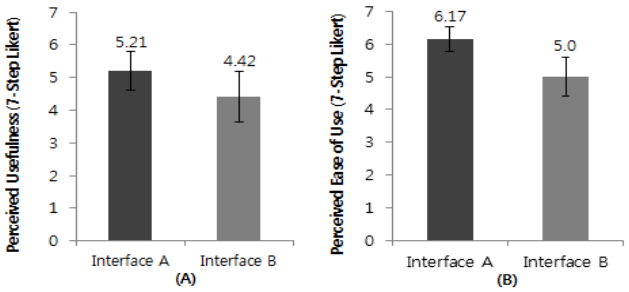

Figure 16. Mean of (A) perceived usefulness (B) perceived ease of use

User's overall emotions while painting

We asked the participants to rate 6 types of emotions during the painting tasks, and the results are shown in Figure 17. The interface A had higher scores than the interface B in Aesthetic, Satisfaction in Usability, Novelty, Uncomftableness, Pleasure, and Excellence, and all of them had significant differences (paired samples T-test, p=0.0, p=0.014, p=0.0, p=0.06, p=0.0, and p=0.09 each).

The interface A had better score than the interface B in Aesthetics. Placement of water and towel and the real watercolor painting tools might have invoked aesthetically positive emotion from the users. Four participants liked the placement of the real watercolor painting tools because it was natural.

A higher score in Satisfaction in Usability of the proposed interface could have been influenced by the function of the watercolor tools. More than half of the participants indicated that the function of the watercolor painting tools resembled the real watercolor painting tools and they could adjust the brush properties easily and intuitively with them.

All of the participants were impressed by the interface and indicated that they had never seen this kind of digital painting interface. While painting, ten participants said they enjoyed painting on the screen and felt it was like a real watercolor painting. It might have influenced Novelty and Pleasure of the interface.

Participants felt that the interface B was more uncomfortable. There were some complaints from the existing digital watercolor painting interface. Three participants were confused the interface B when adjusting the brush properties, and the other three participants felt uncomfortable adjusting the brush properties independently. One participant indicated that the interface B required great skill and it was hard to use.

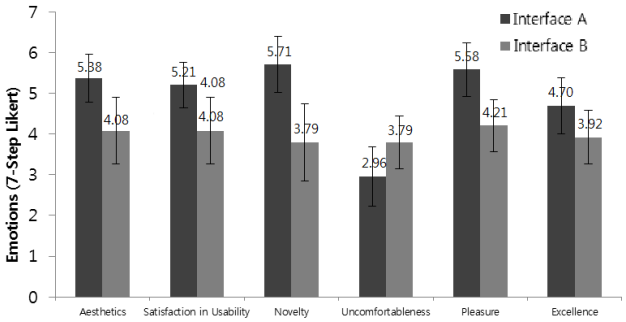

Figure 17. Mean of overall emotions while painting

User Preference

The preference scores of the two interfaces were 5.92 and 4.33 for Interface A and B, respectively, and their difference was statistically significant (paired samples T-test, p=0.032). Participants preferred the proposed interface because the interface was fun, easy, and intuitive. In addition, more than half of them indicated that they could paint more satisfactorily with the proposed interface. Also, over a half of the participants indicated that they could concentrate better on painting in the proposed interface because of the easiness and intuitiveness than existing digital watercolor painting interface. All participants said that the proposed interface would be good for kids and people who are not familiar with digital painting.

There were some limitations of proposed interface. About one third of the participants wanted to keep the mixed color on the palette, which was not supported. Also six participants wanted the visual feedback when the brush properties changing. There was no visual feedback of brush properties changing except a dashboard. Visual feedback like showing the rinsed paint while rinsing the brush would give user more natural feeling of painting.

In addition, there were some feedbacks related to the function of digital painting system. Eight participants wanted the function like zooming the canvas or undoing, supported other typical digital painting systems. Supporting these kinds of function would help the user paint effectively.

CONCLUSION

In this paper, we proposed the digital watercolor painting interface suitable for simulation-based watercolor painting by supporting real watercolor painting processes. We explored the real watercolor painting processes and tools, and drew a design requirement for painting the interface with real watercolor painting tools. Then we made the prototype of the painting interface with the real watercolor painting tools, and compared the usability of the proposed interface with existing digital watercolor painting interface.

The results of the experiment show the interface with real watercolor painting tools did not have much difference in efficiency. However, the proposed interface was more effective in a sense that participants could produce more satisfactory paintings with the proposed interface, and it was easier and more intuitive which made the users more satisfied with the proposed interface. In conclusion, the digital watercolor painting interface with the real watercolor painting tools to support the real watercolor painting process is effective and satisfactory for painting.

ACKNOWLEDGEMENT

This work was supported by the IT R&D program of MKE/KEIT.[KI10041244, SmartTV 2.0 Software Platform]

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