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DESIGNING A USER INTERFACE FOR PAINTING APPLICATIONS TO SUPPORT REAL WATERCOLOR PAINTING PROCESSES

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Abstract. *While research on non-photorealistic rendering provides simulation-based realistic watercolor painting* effects*, the current digital painting interfaces have yet to be improved to provide a realistic watercolor painting* experience*. This study proposes a digital interface to support real watercolor painting processes. We compared the new interface with a conventional digital watercolor painting interface with respect to effectiveness, efficiency, and user satisfaction. The new interface was not different in terms of efficiency, but it was more effective than the conventional interface in enabling the users to produce better paintings. It was also favored in terms of user satisfaction. This result suggests that a user interface supporting real watercolor painting processes is important for the usability of a digital watercolor painting application.*
Keywords: Digital painting, User interface design

1. **Introduction.** Digital painting systems have evolved greatly over the past few decades. In particular, research on non-photorealistic rendering provides simulation-based realistic watercolor painting *effects* [8,21]. However, existing digital painting interfaces do not provide a realistic watercolor painting *experience*. Some studies pointed out that the conventional digital painting systems only took a shallow view of the processes of real painting [4,5]. They lack intuitiveness and naturalness, which are necessary to simulate a real painting experience. For example, watercolorists continuously change the shape and wetness of the brush using painting tools, but the conventional digital painting interfaces do not support this process. This gap between real watercolor painting processes and digital painting interfaces can frustrate watercolorists who have more experience in real watercolor painting. An interface that provides a more realistic experience will help painters utilize the skills that they learned in real watercolor painting, thereby improving the user experience.

Three requirements are essential for a digital painting system to provide a realistic watercolor painting experience. First, it should simulate direct manipulation of the medium. Some digital painting systems use a graphics tablet, which is indirect manipulation and which can cause problems with eye-hand coordination [22]. Second, the basic properties of real painting tools should be considered. For example, a brush is a 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 provide a more realistic painting experience. Finally, real painting processes have to be incorporated in the design. Existing digital painting applications usually provide slide bars and selection boxes to control painting parameters, such as color and brightness. However, in real watercolor painting, different painting effects are produced by changing two or more properties of the tools at the same time. For example, a user can simultaneously change both the wetness and the intensity of a brush by adding water.

Among these three requirements, the first two have been covered in early studies that attempted to create a more realistic digital painting experience. For example, studies have proposed 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 have paid serious attention to the requirement of a digital painting environment that supports the processes of real watercolor painting. Some studies paid attention to the processes of real oil painting, but oil painting processes are different from watercolor painting processes.

In our study, we first investigated the basic skills required and the processes used in real watercolor painting, and then we designed a digital interface that supports those processes. Finally, we evaluated the usability of the new interface against a conventional digital watercolor interface, in terms of effectiveness, efficiency, and user satisfaction.

2. **Related Work.** A number of studies have suggested solutions for bridging the gap between real painting and digital painting by improving the tablet stylus. These studies focused on solving the limitations of indirect manipulation, the lack of tactile feedback as when the brush bends, and the non-intuitive point-based painting of the tablet stylus. CoolPaint, IntuPaint, and MAI Paint Brush proposed digital painting systems that use a brush-like device in a direct manipulation environment, such as a tabletop environment or a mixed-reality environment [12,14,22]. They also support tactile feedback, as when bending the bristles of the brush. Digital Canvas and FluidPaint suggested digital painting systems that used a real paintbrush [17,23] to retain the feel of handling a real brush.

Other studies proposed a user interface with painting tools [3,4,19]. HabilisDraw proposed a tool-based drawing interface, which consists of interface components that mimic physical tools such as a ruler, a compass, and ink wells. It showed that a tool-based approach has some advantages in terms of intuitiveness and ease of use [19]. Baxter's works also suggested an immersive painting environment that mimics a real painting environment [3,4]. However, the interfaces proposed by these studies cannot be applied to watercolor painting, because their intended applications are oil painting and drawing, which have different processes from watercolor painting. However, these studies support our goal of bringing the tools of real watercolor painting into a digital interface to enhance the painting experience.

Watercolor painting is one of the most popular painting methods. Watercolor is a medium that creates distinctive textures and patterns due to the properties of water. The technique produces various effects by controlling the ratio of pigment and water. Painters learn about watercolor painting processes and gain skills through books, art websites, and each other [24,25]. Therefore, most watercolorists have already learned the basic processes and skills to produce the effects that we discuss in the next section.

3. **Watercolor Painting.** We first investigated the processes and skills required in real watercolor painting to understand the user experience that we need to replicate before we started designing our watercolor painting application.

3.1. **Watercolor painting processes.** Watercolor painting consists of two steps as shown in Figure 1: sketching and painting. Sketching is an independent process and is done before watercolor painting. Painting consists of two steps: the adjustment of brush properties and the strokes. We define the brush properties as the color of the paint on the brush, its intensity, and the wetness of the brush. A stroke is a movement that

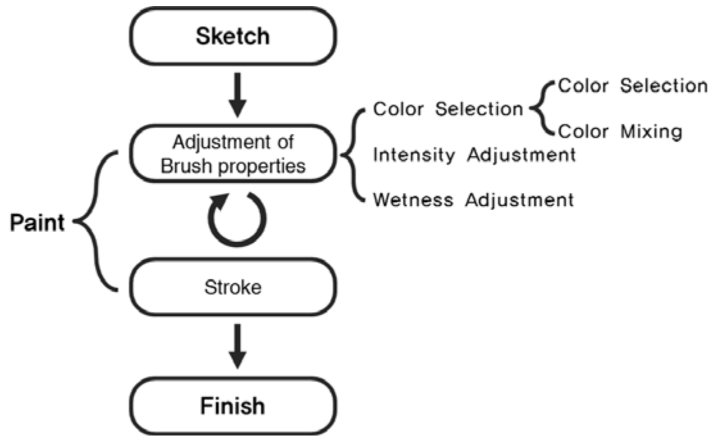


FIGURE 1. Watercolor painting processes

creates a specific mark of the brush on the canvas. Different strokes produce different marks. These two steps are iteratively done during the watercolor painting process.

3.1.1. *Adjustment of brush properties.* The brush can be manipulated to create different watercolor effects, by adjusting the color of the paint on the brush, the intensity of the color, and the wetness of the brush. The color can be changed either by selecting an existing color on a palette or by mixing two or more colors. The intensity of the color can be changed by loading the pigment on a palette or rinsing the brush with the water. The wetness of the brush can be changed by loading the water or drying the brush with the towel. Brush properties may or may not be adjusted, together or individually, depending on the desired effect, and these adjustments are done iteratively with watercolor painting tools.

3.1.2. *Stroke.* The stroke is the primary movement in watercolor painting, making a mark on the canvas using the brush. Various types of marks are possible depending on the brush properties.

3.2. **Watercolor painting tools.**

3.2.1. *Brush.* In real watercolor painting, water, a towel, and a palette are used to change the properties of the brush. Various kinds of watercolor effects like dry-brush, edge darkening, back-runs, granulation, and flow patterns are created by adjusting the wetness of the brush and the color intensity of the paint. The shape and condition of the brush tip also affect the shape of the mark. Depending on the brush tip shape, its wetness, and the paint color, a painter can produce marks with different thicknesses, shapes, and color. Additionally, a painter can understand the approximate value of the intensity and the wetness of the brush through the tip of the brush.

3.2.2. *Watercolor paints and palette.* Watercolor paint determines color, and the purity 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.

3.2.3. *Water and towel.* Water is one of the most important materials in watercolor painting. Various watercolor effects are possible depending on the wetness of the brush. A user rinses the brush with water to prepare for a different paint color. The user can also dip the brush tip in water to increase the wetness of the brush and decrease the intensity of the color that is already loaded on the brush. A towel is used to dry the brush after

FIGURE 2. Six basic skills of watercolor painting

rinsing, and it can also be used to decrease the wetness of the brush even when it already has paint on it.

3.3. **Basic skills of watercolor painting.** There are various techniques in watercolor painting. In this section, we define six basic techniques: Flat Wash, Graded Wash, Glazed Wash, Wet-In-Wet, Dry Brush and Lifting.

Flat Wash is the most basic skill, which involves applying color on the area with consistent intensity and wetness. In digital painting, flat washing does not require any adjustment of the brush properties. **Graded Wash** is painting the area by gradually changing the brush properties. This skill is often used to express the background, such as the sky. **Glazed Wash** is creating a glazed effect by adding thin watercolor layers over a dried layer. **Wet-In-Wet** is adding layers of wet paint on a wet canvas. Accidental effects of watercolor are produced by the flow of water and paint. **Dry Brush** is painting with very little wetness and applying paint only to the raised areas of the paper [8]. It is mostly used to express rough textures. **Lifting** is removing the layers of watercolor with a clean brush, usually when the layer is wet. The lifted area becomes lighter in intensity. This skill is typically used to express light and pale effects, like clouds.

4. **Painting Application Prototype.** We created a prototype by adopting a tabletop interface using a real brush, similar to an earlier study, to avoid the problems of indirect manipulation environment with a graphics tablet [7,17,22,23]. Then, we designed a user interface with tools that resemble the look, use, and function of real watercolor painting tools.

4.1. **System.** The prototype tabletop is a Rear-DI (diffused illumination) type [20] with dimensions 102cm × 79cm × 80cm, and it includes a camera and a projector. The camera has a resolution of 640 × 480 pixels and a frame rate of 22 fps, and it is equipped with an infrared passing filter. The projector has a rating of 2,200 ANSI lumens. The prototype ran on a desktop PC with a 3.2 GHz dual-core CPU and 2 GB RAM.

The prototype detects the blob-shaped area touched by the brush and creates a mark based on the position and the size of the blob. To determine the touched area of the brush, the prototype used Community Core Vision (CCV), which was customized to send TUIO 2D blob messages [7] that contain the position, the orientation and the width and height of the blob. In addition, WetDream was used to simulate realistic watercolor effects. WetDream is an open-source tool created by R. Levien [13] that produces semi-realistic watercolor effects by simulating the flow of watercolor in real-time.

FIGURE 3. Painting with the proposed interface

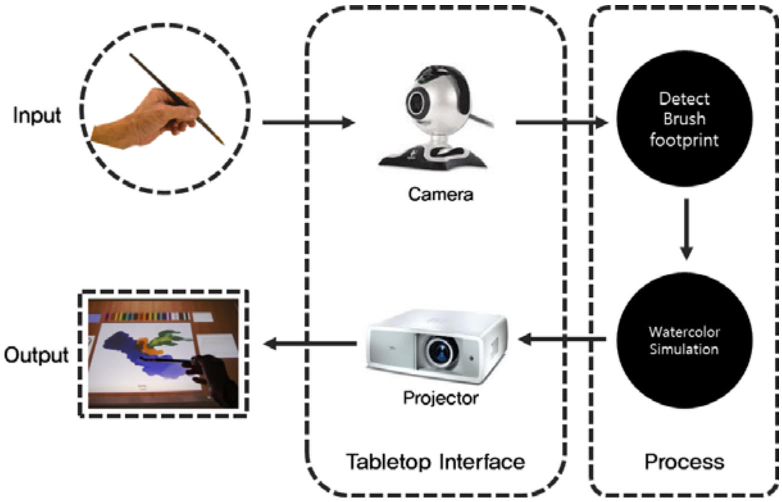


FIGURE 4. Structure of the painting application prototype

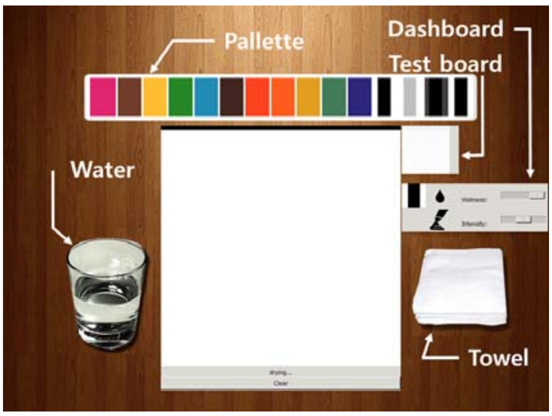


FIGURE 5. User interface of the painting application prototype

4.2. **User interface.** We developed a user interface for digital watercolor painting as shown in Figure 5. It consists of water, a canvas, palette, towel, dashboard, and test board.

4.2.1. *Canvas.* The 500 × 500-pixel canvas is in the center of the screen. The application displays the marks of the brush as an approximate ellipse based on the characteristics of the touched area. As shown in Figure 6, generated marks are different, depending on the

FIGURE 6. Stroke on the canvas

FIGURE 7. Function of the palette

brush properties. When the brush is wet, the brushstroke has white diagonal lines on it. These lines gradually disappear as the blot dries. The stroke with low wetness exhibits a Dry Brush effect, where paint is applied only on the raised areas of the paper.

4.2.2. *Palette.* A palette is placed above the canvas. It has three grayscale colors and eleven colors introduced in Curtis' 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]. Excluding opaque white, every paint color is transparent, and a blended color appears when the user dabs multiple colors on the canvas. On the other hand, opaque white is used for erasing or highlighting. Because one of the three grayscale colors is opaque, all three are shown with both a black background and a white background so that the user can distinguish an opaque color. The palette also includes pure water in the rightmost cell to reset the brush to a transparent state immediately.

The palette is used to load watercolor paint or to increase the intensity of the color on the brush. As the user rubs the brush over a paint cell on the palette, the intensity of the selected color increases as shown in Figure 7.

The palette is also used for mixing colors, like in real watercolor painting. When the user rubs on a paint cell on the palette, the color on the brush will be gradually mixed with the color of the paint cell. For example, if the current color on the brush is yellow and the user rubs the brush over the blue paint cell, the color on the brush becomes green. If the user continues to rub on the blue paint cell, the color on the brush gradually turns blue. Mixing colors by rubbing the brush with the opaque white cell or with the pure water cell is not allowed. When the user rubs on the opaque white cell or on the pure water cell, the color of the brush immediately changes to white or transparent, respectively.

4.2.3. *Water.* Water is represented by an image of clear water contained in a transparent glass to the left of the canvas. The function of water is to decrease the intensity of the color and increase the wetness of the brush at the same time, as shown in Figure 8. As in real watercolor painting, the user can dilute the paint differently by varying the rubbing speed on the image of the water glass. If the user continues to rub the brush on the image

Figure 8. Function of the water

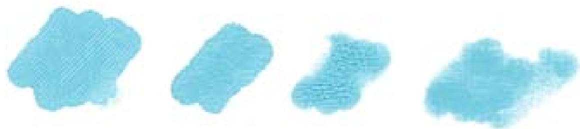


Figure 9. Function of the towel

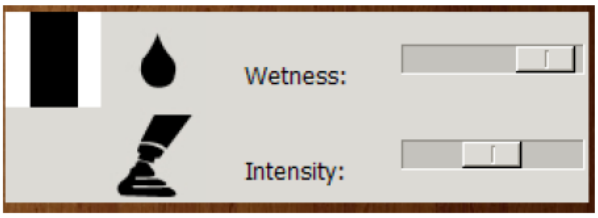


Figure 10. Dashboard showing the brush state

of the water glass, the intensity of the color eventually becomes zero, and the color on the brush becomes transparent, similar to the effect of rubbing the brush on the pure water cell. This act can be compared to rinsing the brush in real watercolor painting.

4.2.4. *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 the brush on the towel, the wetness of the brush decreases depending on the number of rubbings as shown in Figure 9.

4.2.5. *Dashboard.* In digital painting, the user cannot see the current state of the brush, such as the loaded color, the intensity of the color, and the wetness of the brush; therefore, a dashboard was added to the right of the canvas to represent the current state of the brush. As shown in Figure 10, the color of the brush is shown with black background. Further, the wetness and intensity of the color are shown by the slide bars without numeric values. The slide bars are only for display and cannot be adjusted. As in real watercolor painting, the wetness and the intensity of the color are not presented precisely, allowing the user to guess the approximate relative levels of wetness and intensity from the slide bars.

4.2.6. *Test board.* A test board was added to the right of the canvas, so that the user can test the brush before making strokes on the canvas. The stroke on the test board disappears as time passes. The test board may not be needed when an undo function is implemented later.

5. **Evaluation of the User Interface.** We performed an experiment to compare the usability and advantages of our interface with those of a conventional digital watercolor painting interface.

FIGURE 11. Interface B: Traditional user interface to be compared with Interface A

5.1. **Apparatus.** The experiment was conducted using two variations of the digital interface on the same tabletop environment. Interface A is the proposed painting interface shown in Figure 5, and Interface B is the conventional digital painting interface shown in Figure 11. Interface B has slide bars for controlling the wetness and the intensity of the color independently. Additionally, the values of the brush properties are represented with numeric values on the slide bars. The palette of Interface B is used only for selecting a color, not for adjusting the intensity of the color. It does not support mixing colors; instead, a color picker was offered. The color picker enables the user to select the exact color that the user wants. The size of the canvas, color representation, and watercolor simulation are the same as Interface A. Both interfaces were run on the same hardware environment described in the Painting Application 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.

5.2. **Participants.** Twelve volunteers (3 male and 9 female, 21-32 years) participated. All participants were familiar with watercolor painting and had knowledge about watercolor painting tool usage. 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.

5.3. **Tasks.** The experiment consisted of two tasks: painting tutorial and free painting. The painting tutorial task included instructions to complete each painting. We used a tutorial from Watercolorpainting.com, involving the six basic skills of watercolor painting [24]. In the painting tutorial task, pictures for each step were shown, and the description of the step was given in explanation of the skills without the name of the skills. The pictures that must be completed at each step are illustrated in Figure 12. A picture of a participant performing a tutorial task is also shown in Figure 12. In the free painting tasks, participants were asked to paint an apple freely. The photograph of an apple was given, and participants were allowed to paint in any style they wanted. Sample paintings from the experiment are shown in Figure 13.

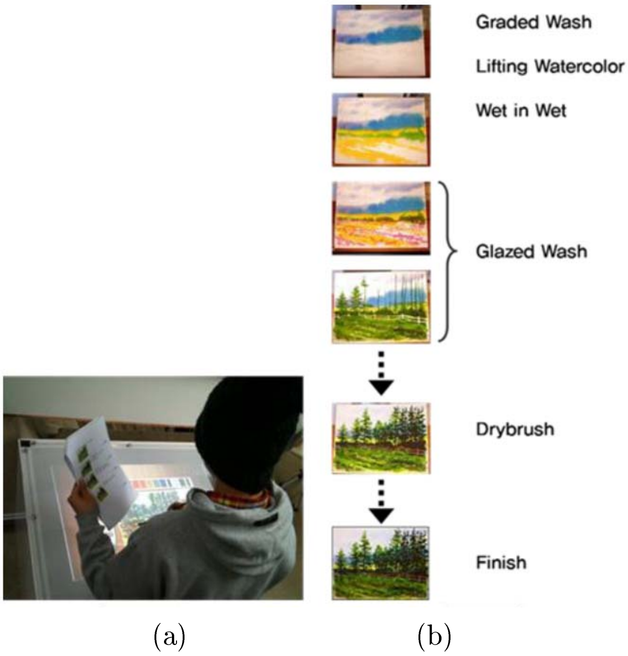


FIGURE 12. (a) A participant performing the assigned task, and (b) the painting tutorial task and the watercolor painting corresponding to each step

FIGURE 13. Sample paintings from the experiment

5.4. **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 approximately 1.5 h per participant. Participants were divided into two groups, and each group started with a different interface. Every participant did a free painting task after the painting tutorial task. Participants were asked to paint as close to their usual methods as possible. After each task, we asked the participants to fill out a user questionnaire with 7-step Likert scale questions, and then we had a short debriefing session.

5.5. **Measures.** To evaluate the usability of the two interfaces, we measured the effectiveness and the efficiency of the interfaces, as well as the satisfaction level of participants with the interfaces. To measure the effectiveness of the digital watercolor painting system, we asked the users to rate their satisfaction regarding the aesthetic qualities of the work they did with each interface. To measure the efficiency, we measured the total time spent on free painting and the time spent on improving the six watercolor painting skills. To measure the satisfaction level of participants, we asked them to fill out a questionnaire, which included questions about the perceived usefulness and the perceived ease of use of the interfaces, and their interface preference.

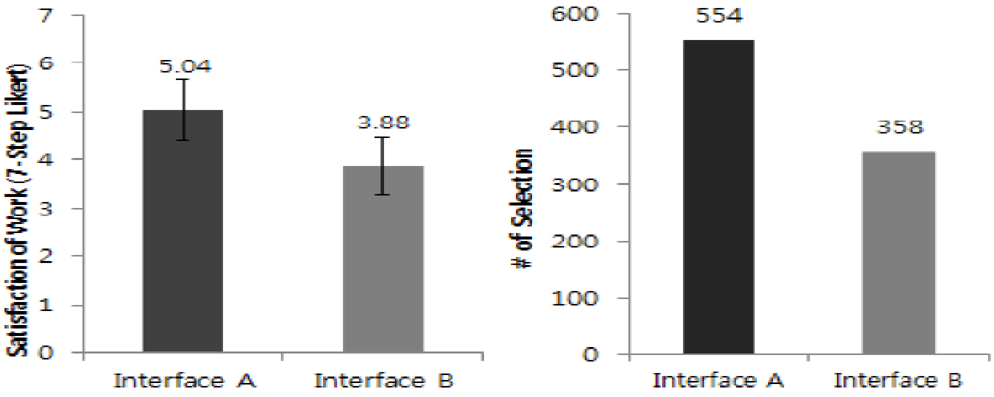
Besides measuring these aspects, the users also reported their overall feelings about the experiment using a questionnaire with the scale developed by Jeong [11]. The questionnaire consisted of six categories: Aesthetics, Satisfaction in Usability, Novelty, Discomfort, Pleasure and Excellence. Aesthetics is the positive emotion based on various visual information of the system. Satisfaction in Usability is the positive emotion based on the usability or practical aspect of the system. Novelty is the positive emotion based on the originality of the system. Discomfort is the uncomfortable or unpleasant feeling experienced while using the system. Excellence is the positive emotion based on the outstanding aspects of the system. Each question is presented with related adjectives selected by Jeong for convenience.

6. Results and Discussion.

6.1. Effectiveness.

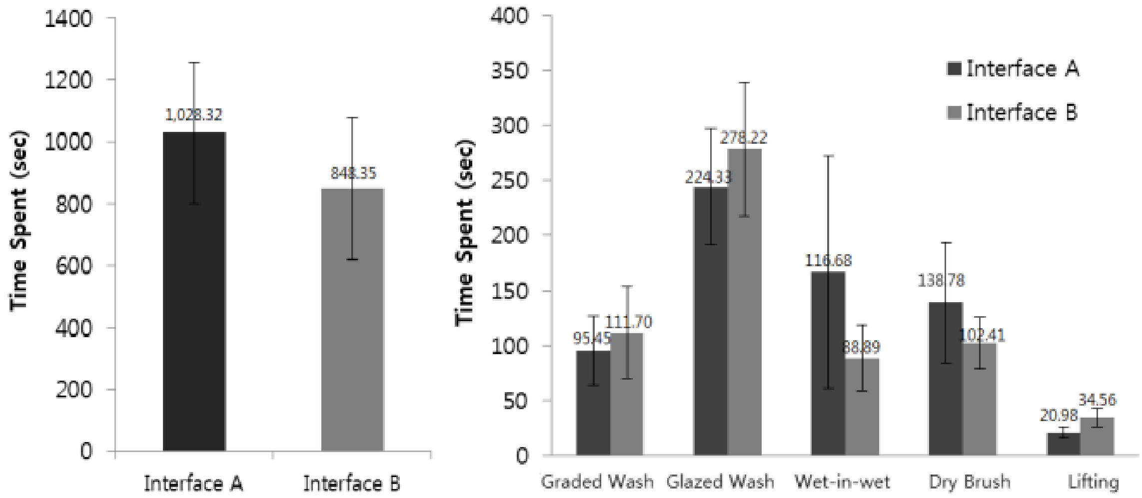
6.1.1. *Satisfaction with the work.* As shown in Figure 14(a), the average score of satisfaction of participants with their work using Interface A was significantly higher than using Interface B (paired samples T-test, $p = 0.001$). The participants could make aesthetically more satisfactory work with our proposed interface, because the watercolor effects were well expressed in the paintings from Interface A than in those from Interface B. More than half of the participants commented that they could use the watercolor technique they wanted, more easily with Interface A than with Interface B. Because the participants could use their experience with real watercolor painting processes using Interface A, they create more aesthetically pleasing work.

In addition, a blind evaluation was performed with people outside the original group of painters to determine their aesthetic satisfaction with the work of the painters in the study. We recruited 38 participants (16 males and 22 females, 20-30 years) from a painting-related online community. These 38 participants were not otherwise involved in the experiment. We showed paintings created by the same painter using the two different interfaces and asked the participants to choose the more aesthetically pleasing one, without giving any information about the paintings. The result of the blind evaluation is shown in Figure 15(b). The paintings from Interface A were preferred by viewers with a significant difference (paired samples T-test, $p < 0.001$). Because both painters and



(a) (b)

FIGURE 14. Mean of aesthetic satisfaction of the work: (a) from participants, (b) from blind evaluation



(a) (b)

FIGURE 15. Mean time spent on the painting tutorial task: (a) total time, (b) time for each of the basic skills of watercolor painting

viewers were more aesthetically pleased with the paintings created with Interface A, we can conclude that Interface A is more effective than Interface B in creating aesthetically more satisfying paintings.

6.2. **Efficiency.** We measured the total time spent and the time spent on each of the six basic watercolor painting skills during the painting tutorial task. We did not measure the time spent on the flat wash, because it is a simple skill that does not require adjustments of the brush properties, so there was no difference in time between the two interfaces.

The total time spent on Interface B was shorter than that of Interface A, but the time difference was not statistically significant (paired samples T-test, $p = 0.174$). For Lifting Watercolor, the participants took less time with Interface A than with Interface B, and the difference was statistically significant (paired samples T-test, $p = 0.017$). In other skills, however, the differences between the two interfaces were not significant. Participants could not easily control the brush property values with Interface A, and they seemed to need more training to set the brush the way they want. Two participants who were

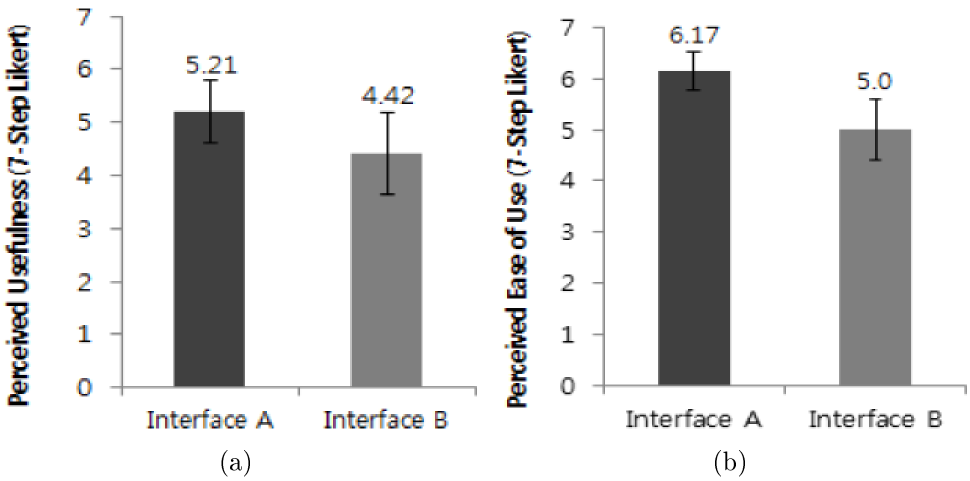


FIGURE 16. Mean of (a) perceived usefulness (b) perceived ease of use

familiar with a digital painting interface commented that Interface B allowed them to set the brush properties to precise values, so they could jump to the desired value. Further, they commented that it took longer to change the brush properties with Interface A than with Interface B. However, the time difference in changing brush properties was not statistically significant. To sum up, we could conclude that there was no significant difference in efficiency between the two interfaces.

6.3. **Satisfaction.**

6.3.1. *Perceived usefulness and perceived ease of use.* The perceived usefulness and the perceived ease of use of each interface are shown in Figure 16. The perceived usefulness of Interface A was higher than that of Interface B, but the difference was not significant (paired samples T-test, $p = 0.067$). However, the perceived ease of use of Interface A was higher than that of Interface B with a significant difference (paired samples T-test, $p < 0.001$). Participants who were accustomed to a conventional digital painting interface indicated that Interface B was effective; participants with little or no experience in digital painting interfaces indicated that Interface A was effective. However, every participant agreed that the proposed interface is easier to use than the conventional digital watercolor painting interface.

6.3.2. *User's overall emotions while painting.* We asked the participants to rate six types of emotions during the painting tasks, and the results are shown in Figure 17. Interface A had higher scores than Interface B in Aesthetics, Satisfaction in Usability, Novelty, Discomfort, 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 $p = 0.09$, respectively).

Interface A had a better score than the Interface B in Aesthetics. The placement of the real watercolor painting tools, such as the water glass and the towel, might have visually evoked positive emotions from the users. Four participants liked the placement of the real watercolor painting tools because it felt 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 functionality of the watercolor painting tools resembled that of real watercolor painting tools, and they could adjust the brush properties easily and intuitively with them.

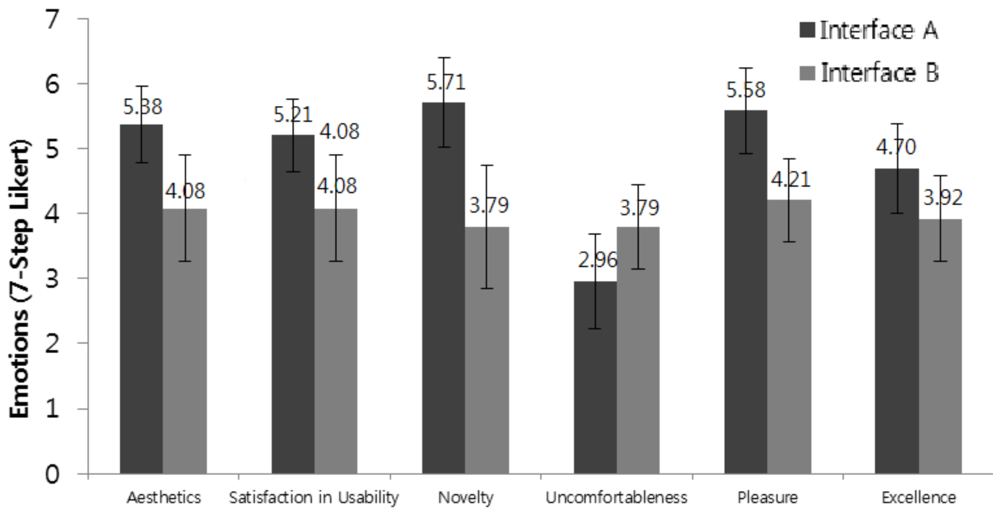


FIGURE 17. Mean of overall emotions while painting

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 similar to real watercolor painting. This enjoyment might have influenced Novelty and Pleasure of the interface as well.

Participants felt that Interface B was more uncomfortable, and they expressed complaints about the conventional digital watercolor painting interface. Three participants were confused with Interface B when adjusting the brush properties; three other participants felt uncomfortable adjusting the brush properties independently. One participant indicated that the Interface B required more effort and was difficult to use.

6.3.3. *User preference.* The preference scores of the two interfaces were 5.92 and 4.33 for Interfaces A and B, respectively, and the 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 our proposed interface. Moreover, over half of the participants indicated that they could concentrate better on painting while using our proposed interface because of better ease-of-use and intuitiveness compared to the conventional digital watercolor painting interface. All participants said that the proposed interface would be good for children and people who are not familiar with digital painting.

However, the proposed interface also had some limitations. About one-third of the participants wanted to keep the mixed color on the palette, a feature that was not supported. Six participants wanted additional visual feedback, besides the dashboard, to give a more natural experience of painting. For example, they prefer to see the rinsed paint while rinsing the brush.

In addition, we received some feedback related to the functionality of the digital painting system. Eight participants wanted functions like zooming the canvas or undoing, which were supported by other digital painting systems. These kinds of function would help the user paint effectively.

7. **Conclusions.** In this paper, we proposed a digital interface that supports real watercolor painting processes. We studied the processes and the tools used by watercolorists.

We designed and built a painting interface prototype with images of real watercolor painting tools. Then we compared the usability of the proposed interface with a conventional digital watercolor painting interface.

The results of the experiment showed that our proposed interface, with real watercolor painting tools, did not significantly differ in terms of efficiency. However, it was more effective in the sense that participants could produce more aesthetically pleasing paintings using the proposed interface. It was also easier to use and more intuitive, which made the users more satisfied. In conclusion, a digital watercolor painting interface designed to simulate real watercolor painting tools is effective and pleasurable to use for painting.

Because the proposed interface is intuitive and easy to learn, it can be incorporated into a painting application for children or people who have difficulties painting with digital interfaces. It can also help children learn watercolor painting.

Although our proposed interface showed better effectiveness and provided greater satisfaction, additional improvements remain for future work. It needs to support a more sophisticated watercolor process. Functions like saving mixed colors on the palette would improve usability. Adding visual and auditory feedback while adjusting the brush properties would also make the user aware of changes in the brush properties. In addition, supporting standard functions, like zooming, panning, copying, or undoing, could help users paint effectively.

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