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Light interaction in the application of home water purification system

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ABSTRACT

Application of lighting effect into water purifying systems was studied to achieve the emotional interaction between users and products. This study involves two groups of experiments. First, the water quality scale corresponding to colours was scored by each subject, and then the colours were classified. Second, the impacts of lighting effect on heart rate, skin temperature, skin electrical signal, and other psychological indices in emotion experiments were studied, which validate that light effect plays a non-negligible role in the emotions of the subjects. By collecting System Usability Scale (SUS) scores, average heart rate, average skin temperature, and skin electrical signal, we compared the results before and after the addition of lighting effect, and validated the influences of lighting effect on human emotions. This study theoretically underlies the application of lighting effect into smart home.

Keywords: Emotion interaction; User experience; Light application; Design method

1. Introduction

Design researchers have focused on different aspects of design and emotion in recent years. Various studies, models and theories have been adopted to explore the relationships of design with emotion and its responses, and to explain how emotion could be effectively applied into design. Different perspectives have also been developed to understand what emotional design should be and the role of emotion in design. Some researchers consider emotion design as a tool that designers can use to deliver their messages and emotions, while others believe it is a kind of experience and response when an individual is using an object. Synaesthesia is a significant method related to design and user emotion. Particular forms of synaesthesia, configuration of joint senses and various sensations all differ among people, but there are yet some general characteristics [1–4]. The following general characteristics of synaesthesia can be specified based on literatures [5,6] and reports [7–9]: synaesthetic sensations are induced involuntarily as reactions to stimuli [1,10,11]; synaesthesia has no influence on the feelings a patient will experience. However, concentrating on the stimulus may significantly affect the strength and consciousness of associations [12–14]. A single stimulus sets off simultaneous perceptions of a number of sensory modalities; for example, listening to piano may evoke simultaneous sensations in the hearing, visual and olfactory modalities [15]. In recent years, the roles of lighting effect in emotional experiences have gained growing attention. Li and Lin [16] thought cloth designers should not only pay attention to the simple visual effect but also use light to express the different emotions of users with the surrounding people and environment (Fig. 1).

Elements need to be considered when light is used in cloth design to express the thoughts and various emotions of the wearer and surrounding people, and to design contextual interaction rather than simply for visual effects [16].

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Fig. 1. Light application in cloth design.

Aliakseyeu et al. [17] used a tap sensor into smart home and successfully controlled the lighting effect through the use of gentle interaction, providing users the pleasure of enjoyment and interaction. Light is not always helpful for interaction, but is harmful sometimes. For instance, are peripheral lighting-based notifications less distracting than traditional dialog-based notifications and to what extent do users feel distracted when using notifications. In this study, when illumination was added into the water purifying system to express the different emotional interactions with the users, the interactive emotions involved the impacts of light on personal emotions, rather than being only displaying the visual effect.

2. Methodology

2.1. Participants

10 students (6 females, 4 males) aged 26 years old on average (N = 20, SD = 2.02) and from different occupations participated in the experiments. They spent no less than an hour doing housework every day and did not report any vision problem.

2.2. Equipment

An AD Instruments Production PowerLab multi-channel physiological signal acquisition system and its Chart5 signal recording and analysis software were used at the analysis modules of galvanic skin response (GSR) and heart rate variability. One personal computer was used to broadcast the experimental material to induce emotion, and another computer was connected to PowerLab for signal acquisition and processing and to a camera to the experimenter covert surveillance for the expression behaviors of subjects. Other instruments included homemade form subjective mood, a light emitting diode light source environment multi-channel colour simulation, a pair of headphones (asked the subjects to isolate interference), and SPSS10.0 for Windows.

2.3. Procedures

A quality measuring sensor and optical sensors were put in the interior of a water purification system to acquire visual feedback. In the first experiment of lighting classification, according to TDS < 1,000 mg/L in "Drinking Water Health Standards", and the best water for health with TDS = 300 mg/L and hardness = 170 mg/L defined by Dr. Martin, we set TDS = 300 mg/L as the best water quality for health. The water quality and colour of light were scored by using the System Usability Scale (SUS).

2.3.1. First experiment: lighting classification

We took the three primary colours red, green and blue (700, 546.1 and 435.8 nm, respectively) for any kind of light colour and clear water quality (TDS = 100–300 mg/L), and the water pollution (300 mg/L < TDS < 1,000 mg/L) corresponding to the description for SUS score. We assumed the dirty chaos, nervous, fault words describe the corresponding water pollution such as (is), and the opposite words describe the corresponding clear water quality (Table 1).

2.3.2. Second experiment: lighting effect of human emotion

Step 1: Basic information was gathered from the participants, including age, occupation, vision status and average time of doing housework each day.

Step 2: All the participants can book 2–3 d before the appointment time. When an experiment began, the experimenter guided one participant into the laboratory to familiarize with the environment, and made some common-sense conversation to reduce his/her pressure and let him/her relax. We make sure this experiment does not harm his/her body and will keep the participant's basic information secret.

Step 3: The experiment was conducted in a darkened room with the area surrounding the display covered with a matte black surface to avoid visual distraction from the monitor's face plate.

Step 4: After getting familiar with the environment, the participants were asked to watch the video to evoke their emotions. Experiment instruction was "We will play you 6 segments of photosynthetic efficiency experiment. Please select a comfortable pose before formal play, relax for some time, try to get rid of the inner thoughts and ideas, relax and rest. Then we will let you see the experiment segment. In the process of restraint, do not suppress your feelings, or deliberately exaggerate your feelings. Try to keep the body untouched, otherwise we will have a very strong signal collected in the interference. Please cooperate with this experiment. Thank you!".

Step 5: After a subject finished watching a clip of video, he/she was asked to immediately fill in an emotion subjective feeling table on the Likert scale, which ensured the evaluation results corresponded to the emotional feelings one to one (Table 2). Before the next clip, the subject should try to disengage from the previous emotion, so it would not interfere with the next clip.

Step 6: After 24 h, the first group of experiments, the second group with the addition of light effect was conducted. The red light and blue light selected from the first group of experiments were used separately as the background light, and the above experimental procedures were repeated.

3. Results and discussion

3.1. SUS

Analysis of the SUS in the first group of experiments is shown in Fig. 1. The original red light was replaced by other colour of light, and the light data in each group were obtained (Table 3). The water pollution corresponding to the control group was set (300 mg/L < TDS < 1,000 mg/L). The first step of data processing was to determine the conversion score of each question, within the range 0–4. For the positive questions (odd number), the conversion scores were determined by subtracting 1 from the original scale scores (Xi – 1); for the reverse questions (even number), the conversion scores were estimated by subtracting the original scores from 5 (5 – Xi). The conversion scores of all questions were added together and multiplied by 2.5, resulting in the total score of SUS. The SUS scores fell within 0–100 and increased at an increment of 2.5. The SUS scores were converted to percentages, which more visually reflected the usability of data.

3.2. Physiological data extraction

The physiological signals collected here included GSR, skin temperature (SKT) and respiratory (R) [11]. The collection frequency was 400/S: the power supply frequency interference of 50 Hz, the low-frequency disturbance due to body movements, and the high-frequency interference due to other factors were filtered from Chart5.

The original data of GSR, SKT and R from one subject watching a frying clip, a happy clip and a relaxed clip without and with the addition of blue background light after 1 min (Fig. 2). The blue and black lines represent the physiological data with and without the addition of blue light, respectively. The original data of GSR, SKT and R from one subject watching a frying clip, a happy clip and a relaxed clip without and with the addition of red background light after 1 min (Fig. 3). The red and black lines represent the physiological data with and without the addition of red light, respectively.

Table 1
SUS rating of lighting classification

Red	Strongly disagree				Strongly agree
I think the red light makes me feel dirty, muddy, and chaos	1	2	3	4	5
I think the red light makes me feel clear and pure	1	2	3	4	5
I think the red light makes me feel nervous	1	2	3	4	5
I think the red light makes me feel warm and peaceful	1	2	3	4	5
When I see red light, I think something is wrong, or something has been broken down	1	2	3	4	5
Red light makes me feel everything smooth and orderly	1	2	3	4	5
I think the red light makes me feel nausea, and loss of appetite	1	2	3	4	5
I think red light makes me feel at home and good appetite	1	2	3	4	5
I think the red light is very good identification meaning, I can guess what is mean	1	2	3	4	5
I feel I need other auxiliary hint to recognize red signal	1	2	3	4	5

Table 2
Report on the subjective mood

	Happy	Angry	Hating	Interested	Sad	Amazing	Fearful	Painful	Relaxed	Nervous
Section 1										
Section 2										
Section 3										
Section 4										

0-rarely; 1-a little; 2-nearly; 3-almost; 4-strongly.

Table 3
Original data of the 10 participants in SUS rating

	Male				Female					
	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 5	NO.6
Red	3	4	5	4	4	5	4	5	5	3
	1	2	1	1	2	2	1	2	1	1
	5	5	4	3	4	3	3	5	4	4
	2	1	3	2	1	1	2	3	2	1
	5	4	4	5	3	4	5	5	5	3
	1	1	2	2	2	3	2	1	2	1
	4	5	4	5	4	5	5	4	5	3
	1	2	2	1	2	1	2	1	2	1
	5	4	5	3	5	5	5	5	5	5
	2	1	1	1	2	1	1	1	2	3
Green	1	2	1	1	2	1	1	1	2	2
	5	3	5	5	3	5	3	5	4	3
	1	2	2	2	2	2	2	1	2	1
	5	5	5	5	5	5	5	4	5	3
	1	1	1	1	1	1	2	2	3	1
	5	4	5	5	5	3	5	3	5	4
	1	2	2	2	1	2	2	5	5	4
	4	4	4	4	4	5	4	4	4	3
	2	1	2	2	1	1	2	1	3	2
	4	5	3	3	3	2	5	4	4	4
Blue	1	1	1	1	2	2	1	1	1	3
	5	5	4	4	4	3	2	5	2	5
	1	1	1	1	1	2	1	1	1	2
	5	5	5	5	5	5	5	4	5	5
	1	1	1	2	2	2	2	1	3	1
	5	5	4	3	4	3	5	5	5	5
	1	1	1	1	1	2	1	2	1	3
	5	5	5	3	5	3	5	4	4	5
	2	2	1	2	1	1	1	3	1	1
	3	5	3	5	3	5	5	4	5	5

3.3. Effects of lighting effect on users

In terms of emotional experience, the emotions of waking users could be evaluated by using skin electrical signal, electro-cardio signal and electroencephalogram [18]. The level of skin electrical signal, electro-cardio signal and α wave is relatively sensitive indicators. However, there is no consensus on the research of emotional evaluation or type identification [19]. The study how to quantitatively differentiate various emotional statuses is still not completed. Existing research showing the variation of traditional emotional indicators, including skin electrical signal, electro-cardio signal and electroencephalogram, is unable to differentiate various emotions, but only reflects the level of biological awakening. This conclusion is verified by the research of user experience again. Researchers have tried multiple sets of biological data to monitor users' types of emotion and the status of involvement.

3.3.1. First experiment

Results show that people prefer to use red light to express their requirements and feel easier to associate with danger and some negative emotions. In contrast, the blue light makes people want to drink water and have positive emotion. Results show the users' sensory is relevant and consistent for different types of light. People always confuse the sensors of blue and green.

3.3.2. Second experiment

Comparing the emotional stimuli performed with a single video and after adding two background colours, we found the subjects had different or even opposite expressions of physiological emotions, indicating that light effect plays a role in determining human emotions.

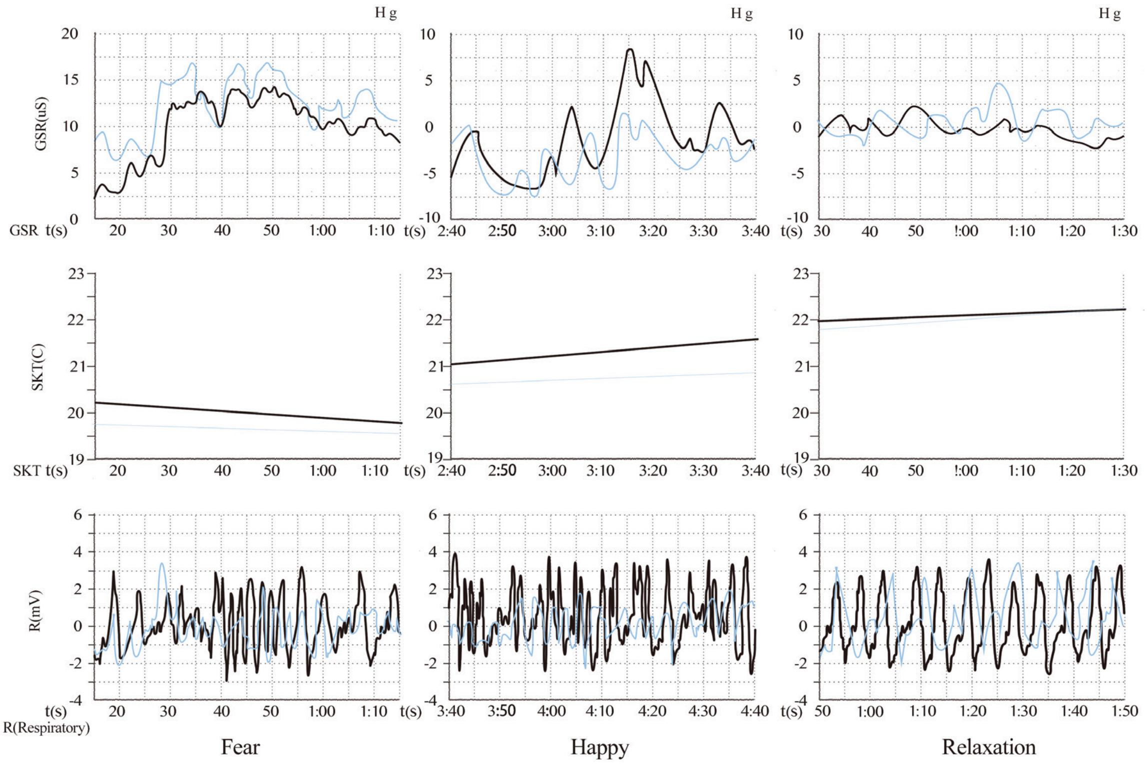

Fig. 2. Original data of one participant in emotion test show the comparison with and without the addition of blue light.

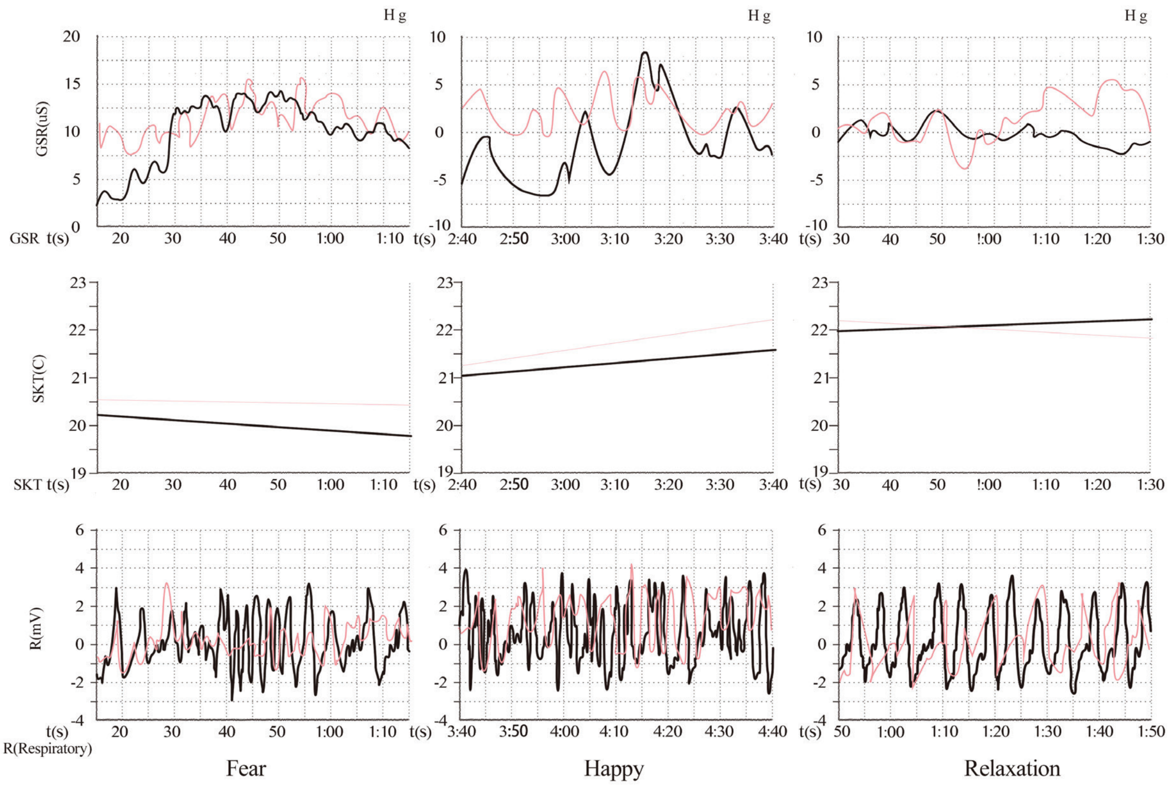

Fig. 3. Original data of one participant in emotion test show the comparison with and without the addition of red light.

4. Conclusions

The two groups of experiments suggest environmental light plays a role in user emotion, which increases the potential of research on interactive design and its practical application. The study started with synaesthesia experience, which created more possibility for users. The experiences of traditional users suggest synaesthesia requires much more sensational interaction to trigger user experience [1,20]. The synaesthetic experience becomes increasingly popular in smart homes. A growing number of designers are paying attention to using synaesthetic interaction to bring different experiences. This article verifies that light efficiency affects the user's choice of emotions through experiments. Then the user's emotional experience can be enhanced by adding light effect interactions into home purification water systems.

(1) Biological signals were prioritized to supplement the observation of facial expression and action and the report of subjective emotional sensations. This is an effective means to recognize emotions, gain more objective and accurate data, and improve the rate of emotions recognized.
(2) A proper experimental plan was used to produce desired outcome of emotional triggering.
(3) The experimental plan and the variation due to emotional triggering were compared through the addition of environmental light, which was basically proven to have a non-negligible effect on users' emotional triggering.

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