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Investigating Effects of Light Animations on Perceptions of a Computer: Preliminary Results

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Abstract— **A preliminary experiment is carried out to investigate the effects of LED light animations on a user's perception of a computer. As anthropomorphism has become an important factor in interaction design, current research tends to add human-like expression abilities to interactive devices. Such methods, however, have limitations as they are complex and not applicable to many currently-in-use appearance-constrained devices such as personal computers. Thus, in this work we investigate an alternative method: expressive light. We attached a programmable RGB LED strip to the front-bottom of a monitor and developed a ping pong game for carrying out an experiment. We collected both game log and questionnaire data from participants. Our results show that participants who played the game with LED light animations liked the game more and perceived the computer as better and more human-like. In addition, no evidence suggested a negative effect on a user's task performance or lead to additional workload.**

I. INTRODUCTION

Electronic devices such as computers are widely used in our daily lives, either personally or publicly. They are used in various applications such as education, entertainment, and information services. In all cases, it is important for such devices to guarantee their users a pleasant and natural interaction experience. Such an objective has become an important research topic in human-computer interaction (HCI) as well as human-agent interaction (HAI) and human-robot interaction (HRI).

Many factors are related to this goal. Among them, anthropomorphism has been considered as one key factor for interaction design as it can affect a user's perception of a device substantially. According to [1], people interact with computers and new media in much the same way as they interact with other people. Moreover, [2][3] well demonstrated the intrinsic mechanism of humans to anthropomorphize objects. For this reason, various studies tried to reach a more natural interaction design by using anthropomorphism methods such as adding human-like eyes and body parts to a device [4] or providing human-like body movements [5].

Although these studies have shown promising results, their methods are not applicable to many currently-in-use devices such as personal computers as most PCs at present use a keyboard, a mouse, and/or a touchpad as input modalities and a display (monitor) and/or a speaker as output modalities. It can be costly and complex to apply human-like design methods to such PCs. Thus, it is important to investigate new methods that can improve a user's interaction experience while being simple and low cost to apply.

In this work, we probe an alternative modality: expressive light. Light, as an interaction modality, has been widely studied in different fields. Many previous studies in fields such as psychology and HCI have investigated the effect of light and color on human perception. Regarding HCI related studies, a number of researchers used expressive light, including ambient light and point light, for their systems to either express affection [6][7][8][9][10][11] or indicate functional states [12][13][14][15][16]. In particular, a handful of papers discussed affective modulation using light and color [7][17][18]. Therefore, the literature has shown evidence to support the idea that expressive light can be effective for affective interaction design.

In our work, we attached a programmable LED strip to the front-bottom of a monitor. On the basis of previous work [19], we assume that such a place of the monitor is within a user's peripheral visual field and thus will not distract him or her. Fig. 1 shows an overview of our system. We developed a ping pong game for carrying out the experiment. We designed a set of LED light animations for various events that happen during the game, for example, the racket hitting the ball, the racket hitting the walls, and game over. We collected experimental data using a post questionnaire and game log data. Our results suggest that participants who played the game with LED light animations liked the game more and perceived the computer as better and more human-like. The contribution of this work is to provide a simple and effective method for improving the human-computer interaction experience that HCI as well as HRI and HAI researchers and practitioners could readily use.

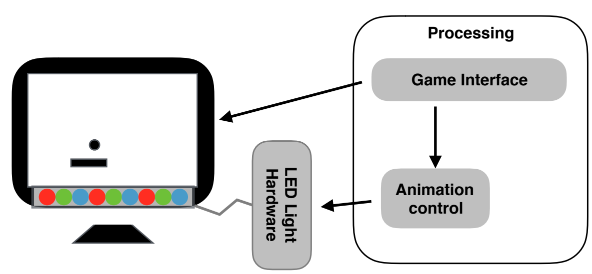

Fig. 1. System overview

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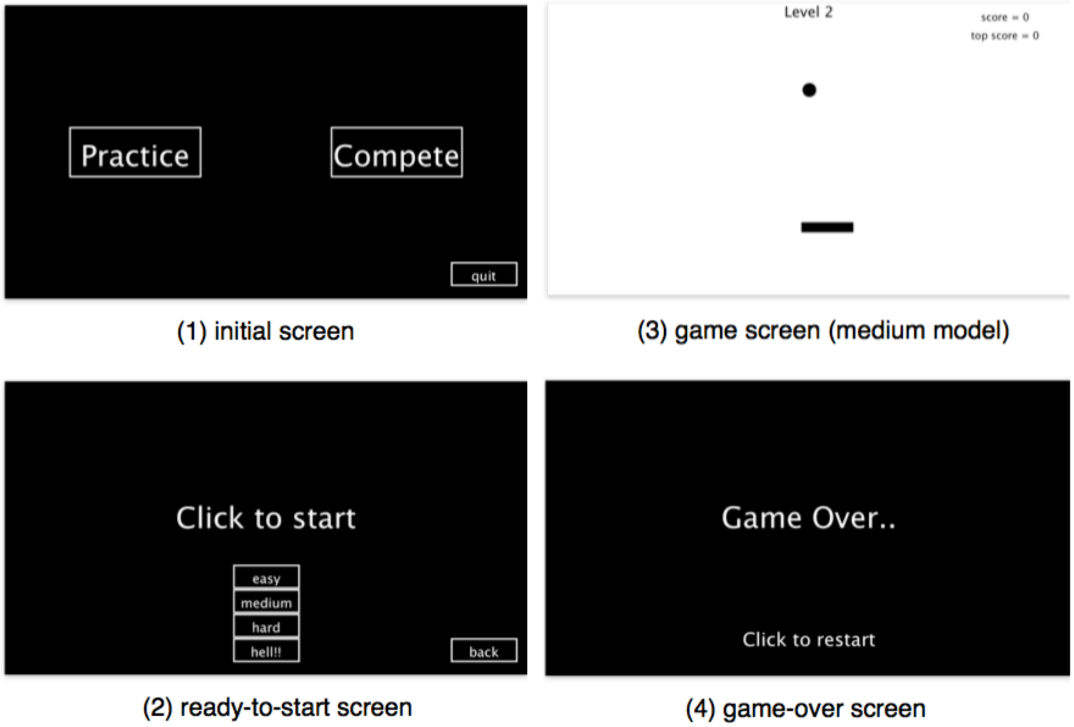


Fig. 2. Four screen shots of ping pong game.

II. EXPERIMENT

A. Ping Pong Game

We developed the ping pong game using Processing. Fig. 2 shows different game screens: an initial screen, ready-to-start screen, in-game screen, and game-over screen. We set the goal of the game as to bounce the ball (moving the racket by mouse) to reach a high score. Four difficulty levels were designed by setting different racket lengths and horizontal forces on the ball when it hits the racket to meet the participants' different gaming abilities. Basically, we designed different scoring metrics with regard to the difficulty levels, where a player gets 1 point each time the ball hits the racket in the easy mode, 2 points in the medium mode, 5 in the hard mode, and 10 in the hell mode. We observed five events in the ping pong game: waiting for game to start, ball hits racket, ball hits wall, playing, and game over. Each event was coded uniquely, and the corresponding code was sent to an Arduino board to control the LED strip to display event-triggered light animations on-the-fly.

B. Light Animation Design

[20] used expressive lights to reveal their mobile service robot's states. As we used the same LED strip, an Adafruit NeoPixel strip with 144 programmable LED pixels per meter, we adapted the light animation pattern definitions from their work. In order to fit the width restriction of our monitor, we used a half meter of the LED strip (72 pixels).

We define an animation A(t) of 72 pixels as a time-varying 72 $\times$ 3 matrix of color intensities:

$$A(t) = \begin{pmatrix} i_{1r} & i_{1g} & i_{1b} \\ i_{2r} & i_{2g} & i_{2b} \\ \vdots & \vdots & \vdots \\ i_{72r} & i_{72g} & i_{72b} \end{pmatrix} \quad (1)$$

,

where the rows represent the indices of pixels and the columns represent the three color channels r, g, and b. The intensity values are the values of the three channels, respectively:

$$\forall : 0 \leq i_{jc_k} \leq 255 j = 1, \cdots, 72; c_k = r, g, b \quad (2)$$

On the basis of the defined animation space A(t), we designed a set of four parameterized light animation patterns: sinusoidal, triangle, swipe, and random (see Fig. 3). Patterns (a)(b) consist of two basic periodic waveforms, sinusoidal and triangle, and (c)(d) are patterns based on the whole LED strip. The parameters I_{min} and I_{max} are the minimum and maximum intensity values for the RGB color channels, and duty ratio D is the ratio of the rise time to period T. Table I demonstrates the set of light animations for each game event. Particularly, the light animation for the game-over event consists of both a sinusoidal pattern (first) and random pattern (after).

C. Experiment Setup

Fig. 4 illustrates the setting of the experiment environment. Basically, a notebook PC was used to run the ping pong game software developed in Processing. A monitor was connected to the notebook PC to display the game. During

TABLE I

SET OF LIGHT ANIMATIONS FOR EACH GAME EVENT

Light Animation	Period (T, second)	Duty Ratio (D)	I_{min}	I_{max}	Event
sinusoidal	2	–	RGB: 0,0,0	RGB: 255,255,255	waiting for game to start
	0.2	–	RGB: 0,0,0	RGB: 255,0,0	game over
triangle	0.6	60%	RGB: 0,0,0	RGB: 0,255,0	ball hits racket
	0.6	60%	RGB: 0,0,0	RGB: 0,0,255	ball hits wall
swipe	–	–	RGB: 255,255,255	RGB: 255,255,255	playing
random	–	–	RGB: 100,100,100	RGB: 255,255,255	game over

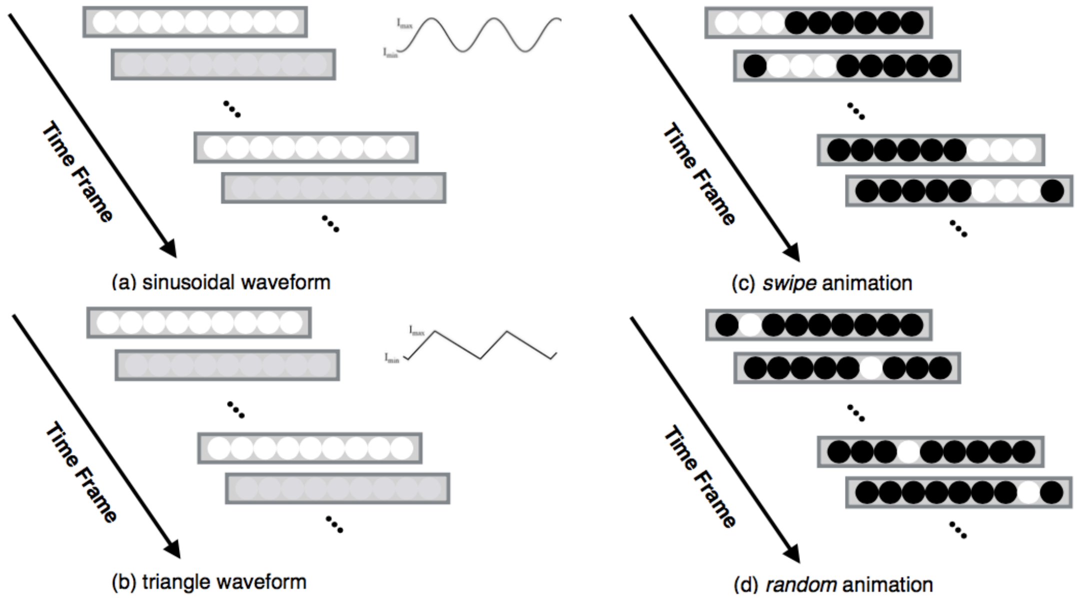


Fig. 3. Set of light patterns we designed for ping pong game.

the experiment, the notebook PC's cover was kept closed, and the game was played via the monitor in full-screen mode. A NeoPixel LED strip was attached to the bottom side of the monitor. The LED strip was controlled by an Arduino UNO board and powered by a 5-V, 10-A AC adaptor. It needs to be clarified that the image in Fig. 4 was taken in a dark environment for the purpose of showing the light effect clearly. The actual experiment was done in a bright environment.

D. Procedure

We recruited twenty-two Japanese in total (9 males) for the experiment. Their ages ranged from 20 to 38 years old (M = 28.09, SD = 6.23). We designed two between-subject conditions: one with light animation and one without light animation.

Basically, the experiment was designed in two phases: a practice phase and a compete phase. In the practice phase, each participant practiced the game freely with access to all four difficulty levels. No time limit was given, so they were able to end the practice phase at any time when they felt comfortable with playing the game. In the compete phase, each participant selected one difficulty level only and played three rounds with regard to this difficulty level. His or her final score was decided as the highest score among the three rounds.

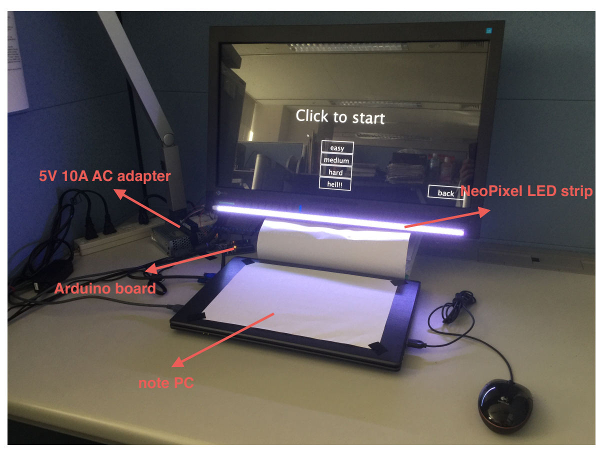


Fig. 4. Setting of experiment environment.

The participants were first welcomed by an experimenter and asked to sign some administrative documents. After this, the experimenter explained the ping pong game to the participants. They were asked to practice the game freely with no time limit before they were ready to "compete" with the others. When the participants thought that they had sufficient practice, they were then required to choose one difficulty mode and play three rounds in the same mode.

TABLE II
SUMMARY OF EVALUATION RESULTS

Category	Sub-category	With light animation		Without light animation		p value
		Mean	SD	Mean	SD	
perception of game	-	5.61	0.57	4.15	1.07	$p < 0.001$
perception of computer	likeness	5.18	0.69	3.59	0.91	$p < 0.001$
	anthropomorphism	2.99	0.86	2.05	1.02	$p < 0.01$
rate of gaming performance	capability	3.09	1.51	2.55	1.37	n.s.
	competitiveness	2.5	1.52	2.64	0.90	n.s.
rate of perceived workload	frustration	3.14	1.29	2.41	1.34	n.s.
	stress	4.64	1.43	4.64	1.57	n.s.
final score	-	77.09	92.96	27.55	14.79	n.s.

E. Post-Questionnaire

We carefully designed our post-questionnaire on the basis of [21][22][23]. It consisted of 22/21 items in total regarding the two experiment conditions with/without LED light animation. The questionnaire used for the with-LED condition contained one more question, "Did you notice the LED light animation?", to check for manipulation. Each questionnaire had three types of items: yes/no questions, 7-point Likert-scale questions, and open questions, where 7-point Likert-scale questions were used the most (18 items). The yes/no questions were used to check for manipulation and for participant-related information.

In particular, the 7-point Likert-scale questions were designed with four main categories: Participant's

- **perception of game** - included questions such as "Do you like this game?" and "Have you enjoyed playing the game?"
- **perception of computer** - included questions such as "How much fun did you have using this computer?", "Do you feel close to the computer?", and "Do you think the computer is alive?"
- **rate of his or her gaming performance** - included questions such as "Do you think you are good at this game?" and "How competitive do you think your score is compared with others?"
- **rate of his or her perceived workload** - included questions such as "Did you feel tired when playing the game?" and "Did you feel pressure during the game?"

III. EVALUATION

Mann-Whitney U tests were used to analyze the experimental data. We first checked whether the participants perceived the game to be different with regards to difficulty. We did not find a significant difference between the with-light-animation condition and the without-light-animation condition (median$_{with}$: 5.45; median$_{without}$: 5; Z = 0.37; n.s.). In addition, we also did not find a significant difference between the two conditions with regard to average practice time (median$_{with}$: 1m 46.5 s; median$_{without}$: 1m 39.5 s; Z = 0.24; n.s.).

Table II summarizes the evaluation results obtained using the Mann-Whitney U test. The participants in the with-light-animation condition liked playing the game significantly more than those in the without-light-animation condition (Fig. 5(a)). Moreover, they also liked (Fig. 5(b)) and anthropomorphized (Fig. 5(c)) the computer more, and particularly, they were more willing to use the computer further in their daily lives. However, the participants' subjectively rated performance and perceived workload indicated no significant difference between the two conditions. This suggests that using light animations might not affect the participants' subjective ratings of their gaming performance, but more importantly, might not cause them extra frustration and stress. The final score shows no significant difference between the two conditions, which also supports the possibility that the participants' real gaming performance might not be affected by the LED light animation.

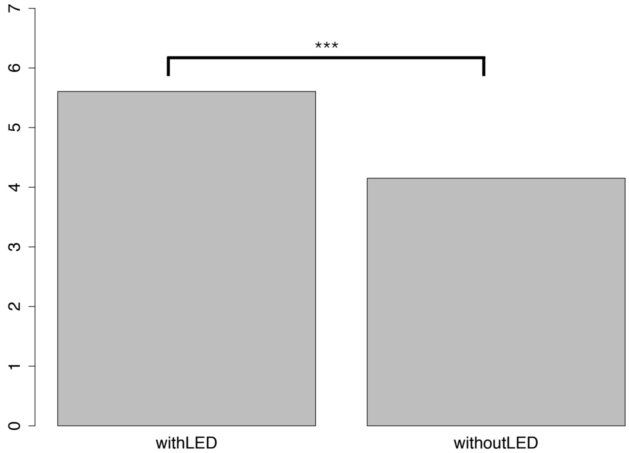
IV. DISCUSSION

Our evaluation suggests that using light animations to improve a user's experience with using a computer is promising. Specifically, we show that light animations can have a positive effect on a user's perception of a computer. This method is simple and therefore can be readily used to currently-in-use devices, as lighting components such as LEDs can be easily embedded to most electronic devices.

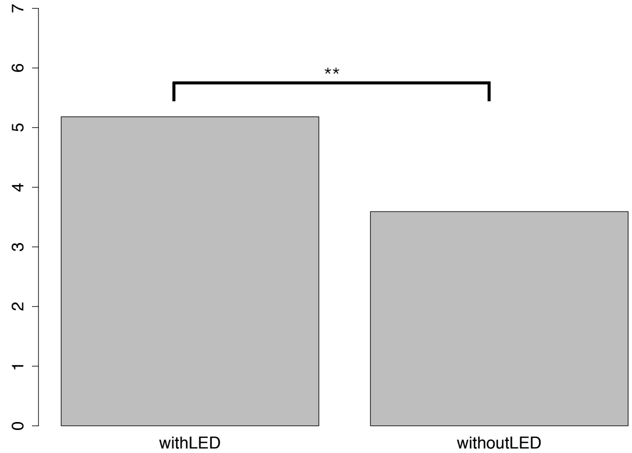
Our results reveal interesting phenomena in which people anthropomorphize devices more when they include light animations. Although the link between light animation and anthropomorphism is unclear, we believe that expressive light can be applied to devices and robots that require affective interaction abilities. At present, an increasing number of intelligent devices and domestic robots (such as cleaning robots) are used in our homes. Applying affective light animations to them will definitely improve their social abilities and achieve more harmonious interaction with people.

In this work, we mounted an LED strip to the front-bottom of a monitor on the basis of previous studies on peripheral cognition technology [19]. Our results indicate that setting an LED strip in such a way will not have a negative effect on a user's task performance and lead to an increase in workload. Thus, such a setting is recommended. However, other settings such as the positions and number of LED strips used to display light animations will be explored in future studies.

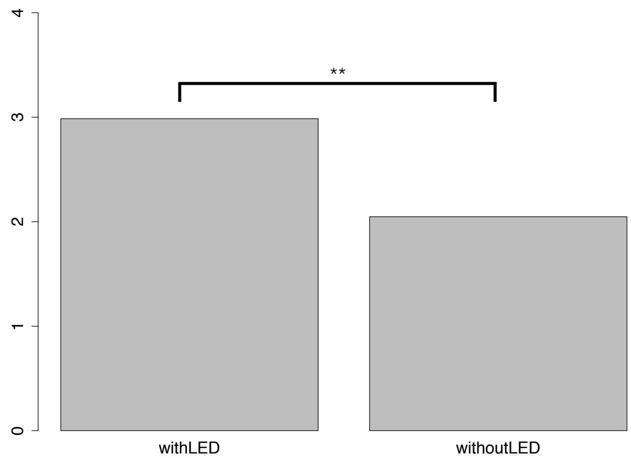
Although in this work we performed the study using a particular ping pong game, we believe that our results can be generalized to other types of tasks. We intentionally made the game simple and difficult (frustrating) to avoid biases that can be caused because of a user's game preferences. Thus,



(a) Perception of the ping pong game.



(b) Perception of the computer: likeness.



(c) Perception of the computer: anthropomorphism.

Fig. 5. Results of participants' perception of the ping pong game, of the computer (likeness), and of the computer (anthropomorphism), respectively.

we believe that our task of playing the ping pong game minimally affected the result. However, investigating other types of tasks such as reading or typing is of interest, and such experiments will be carried out in our following research. In addition, investigation on the appropriate applications is also needed.

In addition, we will use our expressive light method with other devices, particularly appearance-constrained robots [6]. It is essential to uncover how our findings can be generalized and applied in different fields and scenarios.

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