A FRAMEWORK FOR "ENERGY-SAVING STRATEGIES": UTILIZATION OF A CUE OFFERING INTERFACE

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Submitted: Sep. 21, 2014 ***Accepted: Nov. 2, 2014*** ***Published: Dec. 1, 2014***

Abstract- Mass consumption of energy is a big problem. Energy-saving activities which are a solution to this problem have been attracting a lot of attention. Nevertheless, in order to engage in thorough energy-saving activities, consumers need support; on the other hand, even with support, the effects seem to be only temporary. In this paper, to obtain a long-term effect, we focus on developing a method to raise consumers' awareness about energy-saving behavior. To this end, we designed an interface which offers consumers the cue to think about energy-saving activities and conducted a 2week-experiment using the interface with 10 participants. The results suggest two things. First, offering cues increases the number of the energy-saving activities. Second, the more times they perform an activity, the less likely it is that they will change their way of thinking about the activity as time passes. We discuss a more effective method of helping consumers create energy-saving strategies.

Index terms*:* energy-saving activity, human interface, cue offering, sound, eco-feedback.

I. INTRODUCTION

In recent years, people's awareness and interest in power consumption have increased [1]. One of the methods for reducing power consumption is by energy-saving behavior. Consumers do not save as much electricity as they usually expect [1]. In the attempt to help consumers to reduce power consumption more effectively, many studies have investigated the effects of Eco-Feedback System (EFS) on energy-saving behavior [2], [3], [4]. EFS aims at increasing consumers' awareness and interest in power consumption and encouraging them to engage in energy-saving activities. The studies on EFS assume that most people are rational. It is, however, controversial whether people are really rational. The Japanese government is making efforts to make consumers save more power consumption. In this process, many Japanese consumers have answered the questionnaire about energy-saving behavior, an example of the question being asked is whether they think they understand enough about the actions they can take to optimize your electricity consumption [5]. The result of the questionnaire suggests that the consumers have high awareness of and interest in the recent increase in power consumption. Nevertheless, the power consumption in Japan increases year by year [1]. It may be said, then, that most people are not rational about power consumption.

This lack of rationality may come from the fact that people do not know how to engage in energy-saving behavior. Hence, in this study, we focus on what we call the 'energy-saving strategy,' - the strategy one may use in selecting the relevant energy-saving behavior. The source of the strategy is their consciousness about energy-saving. Consciousness and behaviors affect each other [6]. For this reason, we hypothesize that if consumers more often perform energy-saving action, their consciousness about energy-saving will change. A cue of energy-saving behaviors may promote energy-saving action on the side of consumers. The cues can directly convey a chance of energy-saving activities to consumers and affect their action.

We make a cue offering interface and conducted experiments with 10 participants by using the interface and investigate change of participants' awareness and behavior. Our results suggest changing consumers' activities can increase their awareness and the more times they perform activities, the less they decrease their awareness in power consumption.

II. RELATED WORKS

In recent years, many studies have investigated the mechanisms of energy-saving behavior [2], [3], [4], [7]. These studies propose an energy-saving behavior model or a method of supporting for saving energy. Schwartz et al. investigated how people learn about electricity consumption and take action by using a prototype of EFS [8]. They suggested that consumers need a criterion for the comparison of the place and appliance when learning about electricity consumption. In addition, it was suggested that, for changing the behavior we need to change the displayed information according to the level of understanding about the electricity consumption. Hirose proposed a factor model of environment-conscious behavior [9]. Environment conscious behavior includes energy-saving behavior. In this model, the target is environment-consciousness. People assess the value of taking action. They take action or not depending on this value. He et al. considered the energy-saving behavior changing model by means of the transtheoretical model [10]. The transtheoretical model is one of the models of behavior change, used in the medical field. In this model, there are some steps in the behavior change process. There is a best method of supporting the behavior change in each step. They argued that, in order to support behavior changes systems need to be adjusted in each step. These studies focus on energy information, methods of transmitting consumers the information, and effects of energy consumption, without considering effects of energy-saving activities. It is important to examine effects of energy consumption. On the other hand, consumers determine to take action or not, and to install an EFS or not. In order to become sustainable, it is important not only to improve EFS, but also to investigate mechanism of changing consumers' awareness and behaviors.

In this paper, we focus on energy-saving strategy by changing the consciousness via action. To examine simply that action change consciousness, we select power-off action from energy-saving activities. For example, turn off light, display or air conditioner. Switching appliances too often on and off may be inefficient energy usage, nevertheless it is not need consumers' deeply consideration about efficiency. In order to change consumers' power-off action, we offer cue which affect directly the action to them. Based on Hirose's model, the possibility of taking action affects actual power-off actions [9]. By offering cues, i.e. information that consumers can take action, it becomes possible for them to act. If consumers take more action, it is possible to change their consciousness. Moreover, energy-saving strategy can be created by changing their

consciousness. It is necessary to consciously take action, because consumption behavior is habitually taken by consumers [11].

III. DESIGN A CUE OFFERING INTERFACE

a. Energy-saving strategy

In general, when people select to take action or not, they consider surrounding environment. When people are in similar situation, they determine to take action or not based on the experiences. The experiences have one or more reasons. To repeat taking action, their strategies of action are made. We adjust this way of thinking to energy-saving. The surrounding environment is changed by appliances because the power-off action depends on appliances. The experiences are past power-off action. Their strategies which are made by the experiences about power-off action are energy-saving strategies. Figure 1 shows the relationship between constituents of an energy-saving strategy.

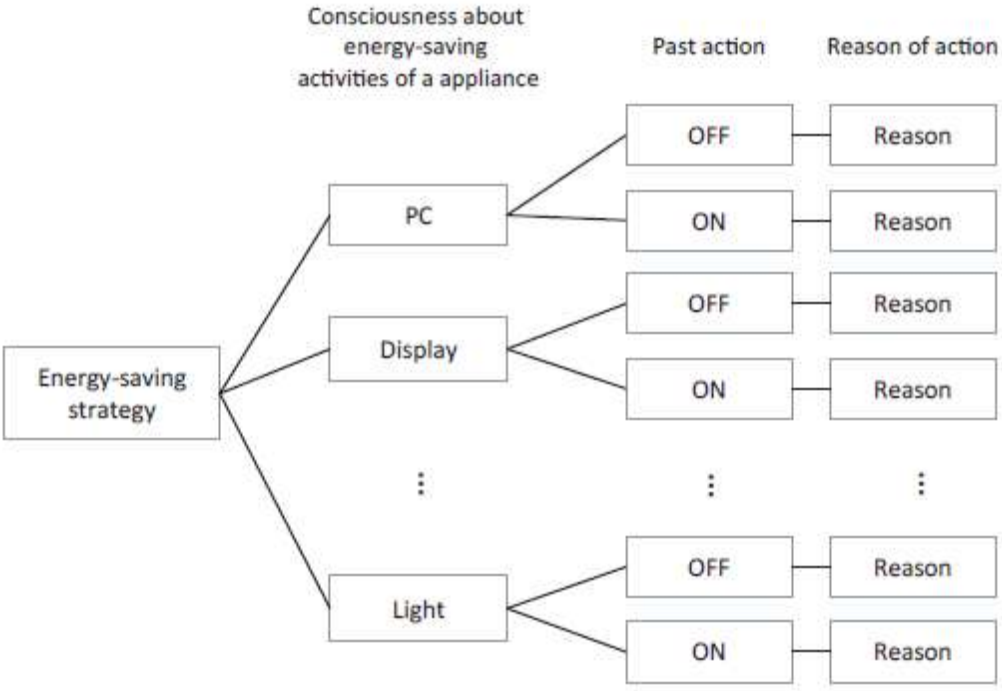

Figure 1. Energy-saving strategy overview

We needed to examine how the consumers perceive each appliance before considering ways to support them. Even though, consciousness about energy-saving is different depending on the situation, there has been no survey taking the situation into consideration. Therefore, we conducted a survey, in which consumers had to imagine the situation in detail. The survey, aimed at examining the consumers' consciousness, was conducted online, as it is easier to respond and collect answers this way. The questionnaire consisted of 16 questions with a 7-point Likert scale (-3: strongly disagree ~ +3: strongly agree). To estimate the energy-saving strategy, participants were asked to consider a situation in detail and answer whether they would take action or not in that situation. Factors such as place, appliance and the time the appliance is on, not in use make up the detailed situation. The place can change consumers' motivation. The way of using is different depending on the appliance, and the time changes electricity consumption. We call the time the appliance on, but not in use "waste time". Consumers were told to consider the place to be their workspace, in order to have similar motivations. Generally, in the workspace, the economic impact, which is one factor changing the consumers' motivation, on the consumers is small. As for appliances, taking the burden of answering into consideration, we selected displays, PCs, lights and air conditioners. They are present in many households and used frequently. As for waste time, taking the burden of answering into consideration, it was classified into short time, medium time and long time. This classification is used only for waste time. In a workspace, short time is, for example the time for going to the rest room, medium time is for example lunch time, and long time is the time after going home and until the next morning.

100 persons answered the online survey. Figure 2 shows the average results of the questionnaire score. In this paper, Time, S, M and L mean waste time, short time, medium time and long time, respectively. In the questionnaire, the average scores are long time > medium time > short time in all appliances and different depending on appliances. This suggests that the longer the waste time is, the more conscious the consumers become. Consumers' consciousness is different depending on appliances. It is necessary to examine the effect of the interface on each waste time and each appliance because consumers' consciousness is different depending on how long the waste time is and what appliance is.

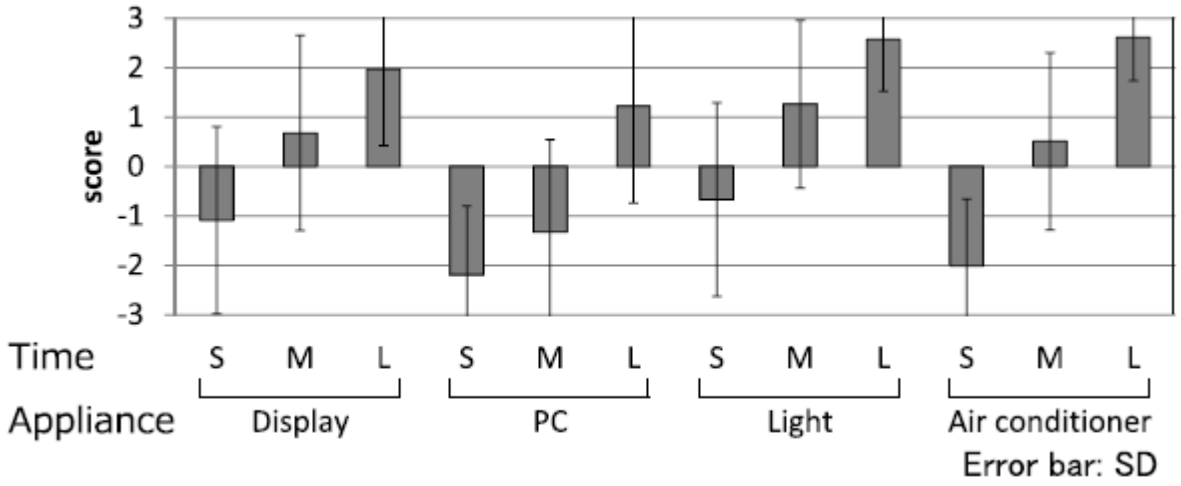

Figure 2. Result of questionnaire about energy-saving

b. Cue Offering

Offering cues is meant to inform the consumers that an appliance is running at a timing, when the consumers are able to perform the power-off action. The timing is different depending on appliances. We define the timing for enabling the consumers to take the power-off action as the moment when the consumers have clearly finished using the appliance, but it is still running. In the case of lights, the timing of finishing using the appliance is when there are no people in a room. Offering cues is simpler than other information offering methods. Therefore, offering cues do not need for consumers to consider about gotten information. Offering cues do not confuse consumers by too many information. In addition, there are a lot of instances when the consumer is able to perform a power action in daily life.

The factor model proposed by Hirose argues that the being able to take action affects taking energy-saving action [9]. Therefore, it is assumed that to inform the consumers about the timing when the action can be taken will enable them to take action. On the basis of this, it is possible that a similar effect will be seen in the power-off action, which are included in the energy-saving actions. In order not to overlook the timing of these instances, we need to observe the situation on all times. In this study, sensors are used for estimating the timing, because it is difficult for us to observe the situation on all times. Specifically, information about appliances’ power and about consumers’ behavior are obtained with sensors, which estimate whether the appliances are running and when consumers finish using them.

Cues are offered automatically, as people cannot supervise the situation continuously. The points to consider are that the cues should be immediate and should not limit the consumers' actions. If cues offer consumers too late, consumers might not associate cues with power-off action. It is preferable offering cues via audio media to doing via visual media, because audio media are more appropriate for announcing the timing than visual media [12]. In this study, we use sounds as cues. We change their parameters depending on appliances, so that consumers can easily distinguish them. If the sound duration is too long or short, consumers might not distinguish. In this study, sound time is one second.

c. The interface and Energy-saving strategy relationship

Figure 3 shows the relationship between the interface, the cue and the energy-saving strategy. Cue happens in consumers' daily life. The cue is caught by the interface via sensors. The interface offers cue to the consumers with sound. The sound would make they take action. To take action affect their awareness and energy-saving strategy. Figure 4 shows the interface overview.

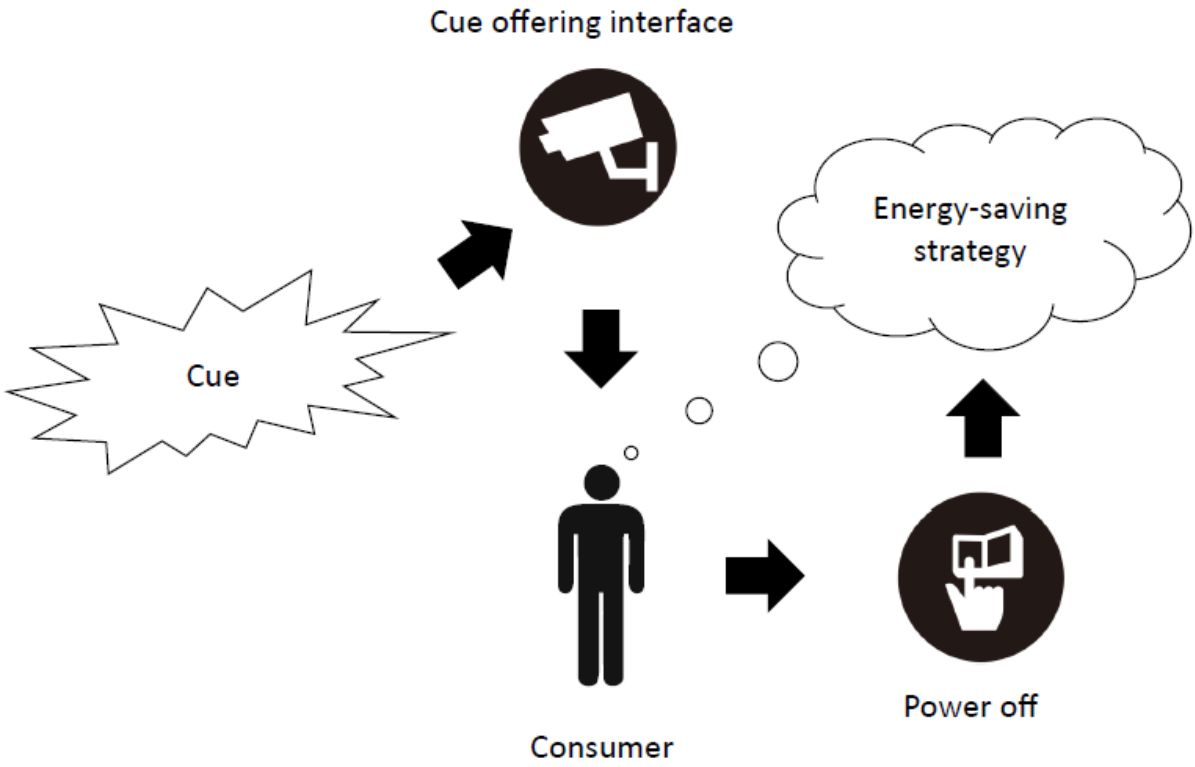

Figure 3. Relation between interface, cue and energy-saving strategy

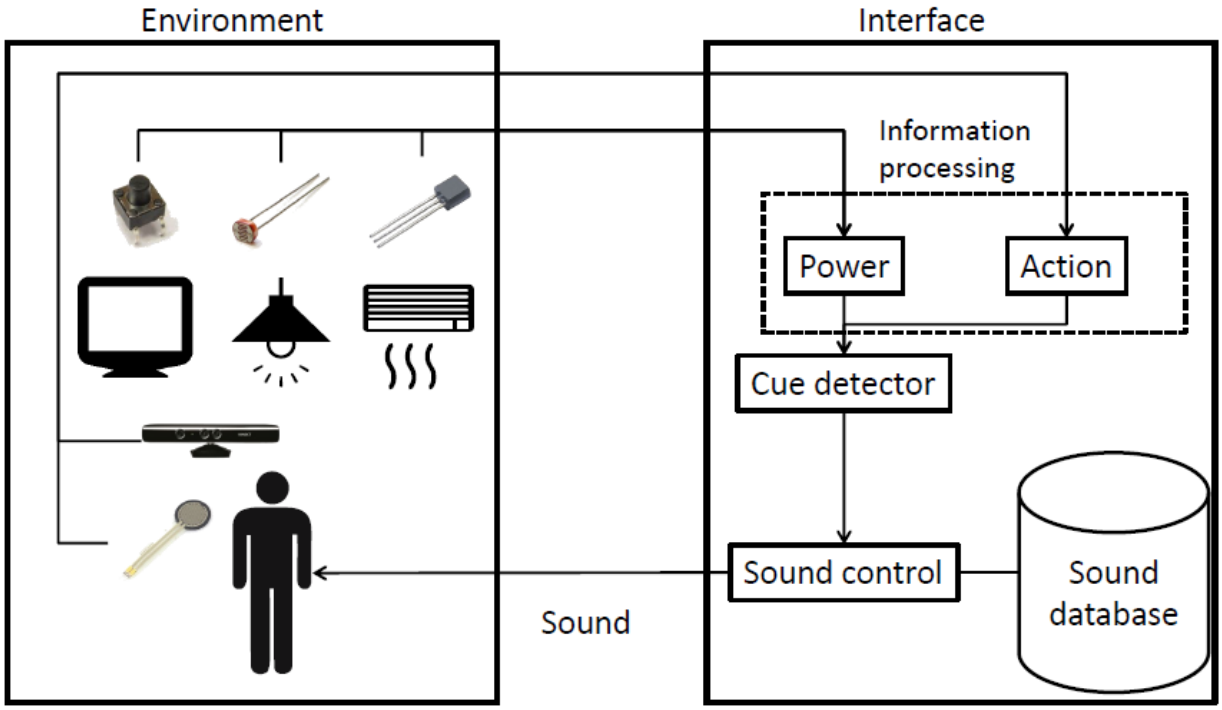

Figure 4. Interface overview

IV. EXPERIMENT

a. Purpose

The purpose of the experiment is to examine whether using cue offering interface changes consumers’ power-off action and energy-saving awareness, and make their energy-saving strategy.

b. Method

The effects of the interface are different depending on the consumer because of the individual variation of the power-off action. To examine the change in the power-off action, we set two experimental periods: one when the interface is used, and one when it is not, hereinafter referred to as the experiment period and the pre-period. We regard the consumer’s life as based on one week cycle. The pre-period is one week. The experiment period is two weeks, as we need to wait to become used to the interface. If there are external factors apart from offering cues, it is difficult to analyze their effect of the interface. We remove external factor as the electric bill and the compulsion from other. To remove the economic cause, the experiment space is the consumers’

workspace. We select the student room for research as the experiment space because the flexibility of consumers' behavior in their workspace is higher than in another space. Furthermore, when we introduce consumers to the interface, we inform them only that it produces some sound when they can take action. 10 people (university student and post-graduate student) participate in the experiment, using a student room for research. Appliances about which cues are offered are displays, PCs, lights, and air conditioners. Table 1 shows the timing of the power-off actions of the appliances. To detect the timing, the system must get information about the consumers' behavior and the state of the appliances (whether they are on or off). Pressure sensors obtain information about consumers leaving their seat, while motion detectors get information about their leaving the room. To get information about the state of the appliances, a switch is added on the display and air conditioner, software is introduced in the PC, and an illuminance sensor is set up in the laboratory. The room has a switch for the air conditioner and light. Each of the participants uses a PC and one or two displays. Doors are closed for simplifying counting the number of participants in the room (see Figure 5).

In this study, we compare in each period the action to cue rate because the number of cues and the number of power-off actions differ from day to day. The action rate is the number of power-off actions divided by the number of cues. To examine changes about consumers' consciousness, we conduct a questionnaire before and after the experiment period. The questionnaire is the same as the online questionnaire. To examine making energy-saving strategy, we need to investigate chronological changes about consumers' consciousness. Therefore, we conduct another questionnaire after an interval and compare its score with that of the questionnaire taken just after the experiment period. In order to compare the action rate after the interval, we make consumers rank the action rate in four periods: pre-period, experiment period, just after the experiment period and after the interval. We compare the energy-saving strategy in three period apart from experiment period by appliances and waste time. The reason is that waste time and the use of appliances affect the power-off action. To examine relation between action and consciousness, we classify the waste time into three levels which are based on the questionnaire. The short time is under 5 minutes, the medium time is 5 to 60 minutes, and the long time is over 60 minutes. To examine the change of participants through this experiment, we conduct half-structured interview. We ask them action reasons and the effect of this experiment to their life style.

Table 1: Power off cue

Appliance	Cue
Display	Leaving seat
PC	Leaving seat
Light	Leaving room
Air conditioner	Leaving room

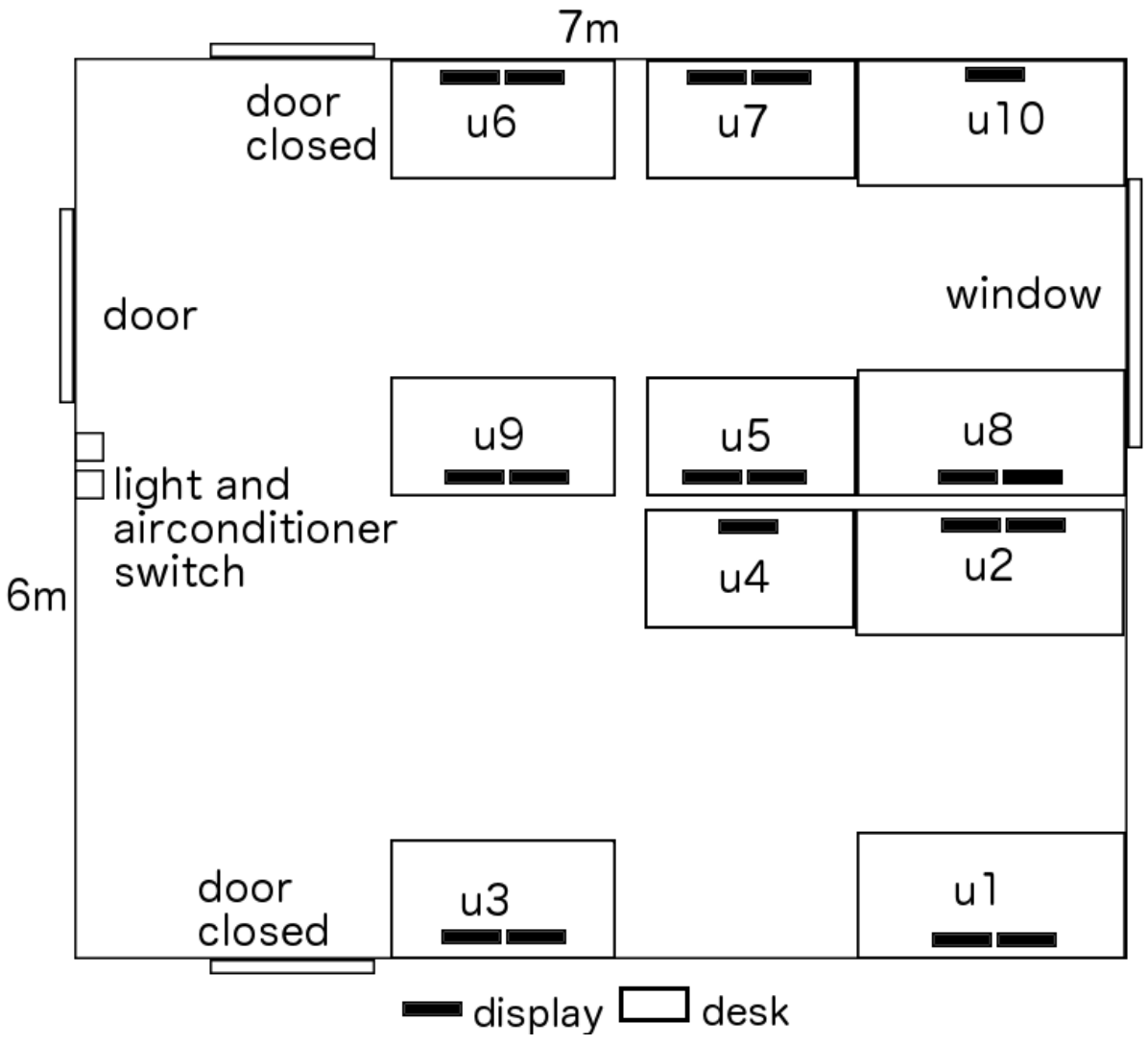

Figure 5. Room arrangement

c. Result

The action to cue rate average of all appliances, all types of waste time and all participants in the pre-period was 1.8% and the experiment period it was 9.7%. Figure 6 shows the action rates according to appliance and time. Consumers did not use the air conditioner in the pre-period and they did not use it for a long time in the experiment period. Thus, its action rate was not calculated and the graph does not contain its action rates. Except for the air conditioner, the action rates are higher in the experiment period than in the pre-period. These results imply that offering cues to consumers can increases the action rate regardless of the appliances. In addition, the action rate is highest in the case of the long time followed by medium time and short time, while the increase of the action rate is different depending on appliances. This suggests that the effect on consumers is higher in the case of a difference in waste time than in the case of a difference of appliance. Table 2 shows the results of the action rate ranking questionnaire. Many consumers answered the period when they performed the most power-off actions is the experiment period. They answered the action rate just after the experiment period is higher than in the pre-period and after the interval. The rank in the pre-period and after the interval are different depending on the appliances. Therefore, we guess that consumers take the most actions during the experiment period regardless of the type of appliances. In addition, we can also infer consumers take more actions just after the experiment period (after they had finished using the interface) than in the pre-period. Offering cues increased the number of actions because the action rates in the case of most appliances and most types of waste time in the experiment period are higher than in the pre-period.

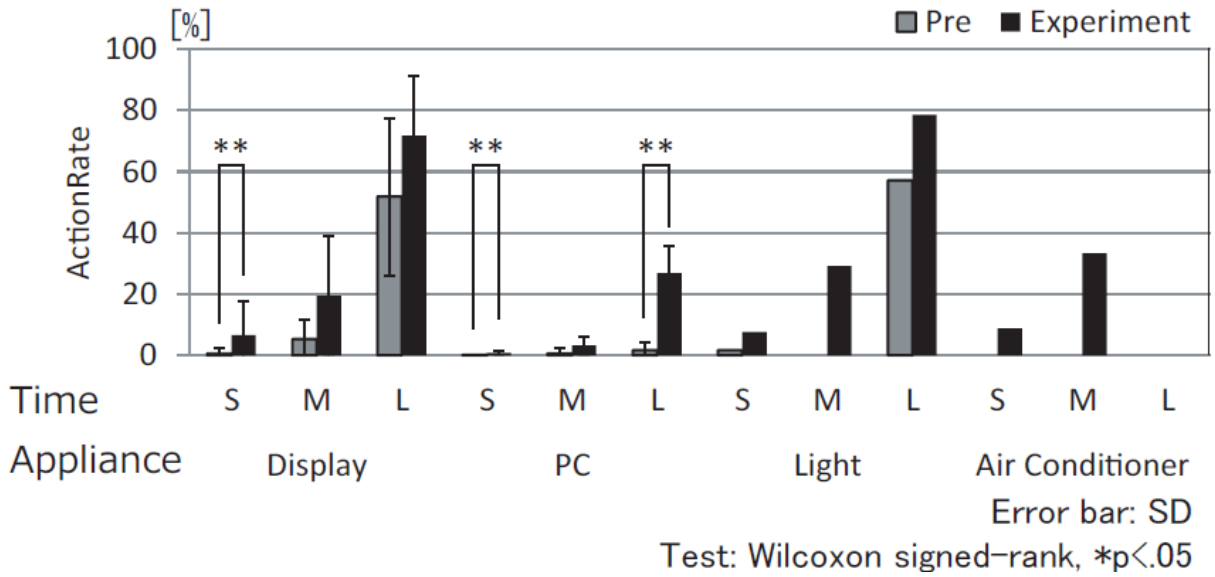

Figure 6. Action rate according to appliance and waste time

Table 2: Result of action rate ranking questionnaire

Appliance	Pre	Experiment	Just after	6 month after
Display	3	1	2	4
PC	4	1	2	3
Light	3	1	1	2
Air conditioner	3	1	2	4

Figure 7 shows the average questionnaire scores by appliances and waste time. In order to examine the effect of the interface, we compared the questionnaire score in the pre-period and the experiment period. 5 scores increased and 5 others decreased, while 2 scores stayed the same. In order to examine the effect in more detail, we compared the number of participants who changed their answers on the questionnaire in the pre-period and the experiment period. Table 3 shows the number of participants who changed the questionnaire answers in the experiment period as compared to the pre-period. The question where most participants' scores increased is the question about displays and short waste time. The number of participants is 6. The question where most participants whose questionnaire score decreased is the question about lights and short waste time. The number of participants is 4. As far as the waste time is concerned, the

number of participants whose questionnaire score changed is higher for medium time, followed by short time and long time. In order to examine the effect of using the interface, we compared the questionnaire scores just after the experiment period and after an interval. Questionnaire scores, which increased and decreased are 2 and 10, respectively. These results show that the consumers' awareness about the power-off actions diminished after using the interface.

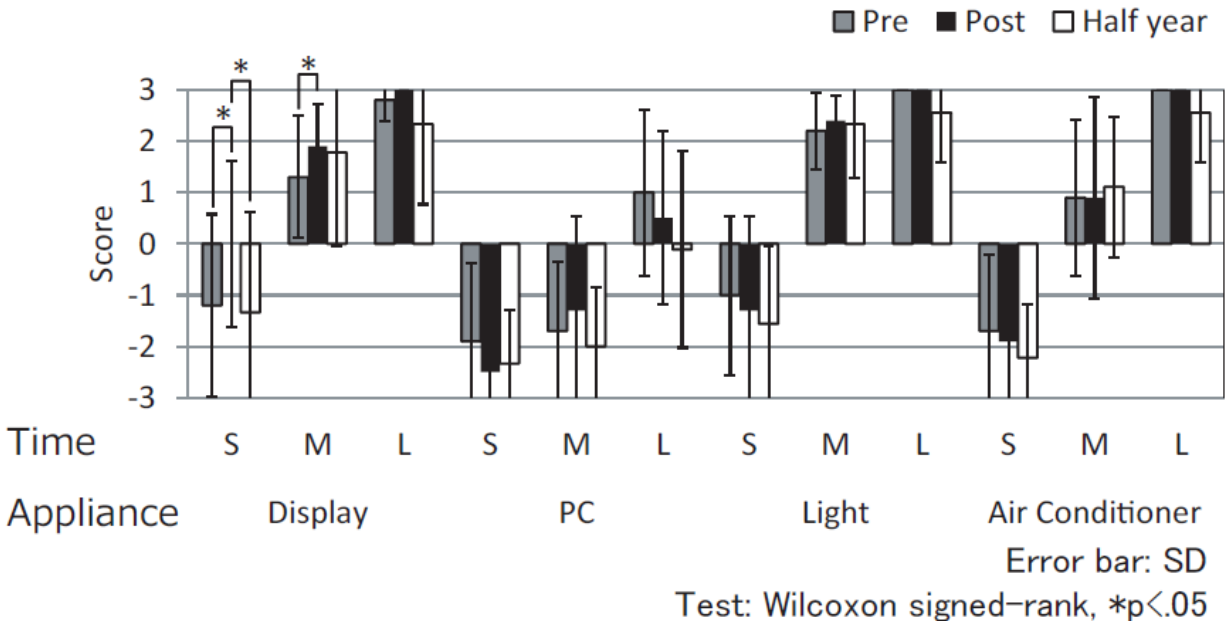

Figure 7. Result of energy-saving questionnaire according to appliances and waste time

Table3: Number of participants whose scores on the questionnaire about energy-saving changed (before and just after using the interface)

Time	Appliance	Up	No change	Down
Short	Display	6	3	1
	PC	1	7	2
	Light	4	2	4
	Air conditioner	2	6	2
Medium	Display	5	5	0
	PC	4	4	2
	Light	5	2	3
	Air conditioner	5	2	3
Long	Display	2	8	0
	PC	1	6	3
	Light	0	10	0
	Air conditioner	0	10	0

In order to examine the effect of the interface, we compared the questionnaire score in the pre-period and after the interval. The questionnaire scores that increased and decreased are 3 and 9, respectively. Table 4 shows the number of participants whose questionnaire scores changed after the interval as compared to the pre-period. The question where most participants' scores increased is the question about displays and medium waste time. The number of participants is 5. The questions where most participants' scores decreased are the questions about displays and air conditioner in short time, light in medium time, and air conditioner in long waste time. The number of participants is 4. As far as waste time is concerned, the number of participants whose questionnaire score changed is higher for medium time, followed by short time and long time. Therefore, it is assumed that consumers become unaware of the power-off actions via this experiment process. As for changing consumers' consciousness by using the interface, increasing the number of actions makes consumers conscious about the power-off action. The action rates in the case of many appliances and many types of waste time are higher in the experiment period than in the pre-period. On the other hand, the scores of five of the questions are higher in the experiment period than in the pre-period and the scores of five of the questions are lower in the

experiment period than in the pre-period. As for the number of participants whose questionnaire scores changed, six questions had a greater number of participants whose scores increased in the experiment period as compared to the pre-period, and two questions had the greater number of participants whose scores decreased in the experiment period as compared to the pre-period. Therefore, we might assume that if the action rate increases, consumers become more conscious about the power-off action. However, this is not necessarily true, because there are some questions whose scores decreased. As for the score changing over time, it is assumed that it slowly decreases after the consumers finish using the interface, as all question scores decreased in the survey performed after an interval. In addition, the rank of the action rate in the experiment period is higher than it in after the interval. Therefore, it is assumed that if the consciousness decreases the action rate decreased too, and vice versa.

Table 4: Number of participants whose scores on the questionnaire about energy-saving changed (before and 6 month after using the interface)

Time	Appliance	Up	No change	Down
Short	Display	2	4	4
	PC	2	5	3
	Light	1	6	3
	Air conditioner	2	4	4
Medium	Display	5	2	3
	PC	2	5	3
	Light	4	2	4
	Air conditioner	4	3	3
Long	Display	2	5	3
	PC	2	4	4
	Light	0	8	2
	Air conditioner	0	7	3

Table 5, 6 shows results of interview. Table 5 shows only the answers changed from before period and that is biggest number of participants. In the case of display, 6 participants answered

they perform power-off action because the alarm rang in experiment period. According this results, we expected the offering cues can motivate them to perform power-off action. Table 6 show only the answers which is biggest number of participants. 4 participants answered the number of times they notice could do something to save energy increased. Therefore, using the interface can make participants more aware of energy-saving. In the case of changing their energy-saving activities, 2 participants started new energy-saving activities. Owing to this, we can estimate using interface make participants start new energy-saving activities.

Table 5: Results of interview about action reason.

Period	Appliance	Action reason (Number of participants)
Pre	Display	Because I did not want my work to be seen by other (4)
	PC	Because I did not want to waste energy (2)
	Light	Because I did not want to waste energy (4)
	Air conditioner	Because I did not want to waste energy (3)
Experiment	Display	Because the alarm rang (6)
	PC	Because I became more aware of energy saving (1) Because all the people in the experiment space do it (1) Because the alarm rang (1)
	Light	
	Air conditioner	
Just after	Display	Out of habit (3)
	PC	Because I can save energy (1)
	Light	
	Air conditioner	
6 months after	Display	When I saw one person warning another (1) Because I started living alone (1)
	PC	Because I was worried about the electricity bill (1)
	Light	
	Air conditioner	Because I felt guilty

Table 6: Results of interview about changing through experiment.

Question	Answer (Number of participants)
What did you notice related to energy saving?	The number of times I would notice that I could do something to save energy increased (4) I became aware of other people's wasteful activities (e.g., keeping displays on)(2)
What did you change about your energy-saving activities?	I decreased the number of displays I was using (1) I would turn off someone else's display if it was wasting energy (1)

V. TOWARD MAKING ENERGY-SAVING STRATEGY

The above-mentioned results might assist as in designing an energy-saving strategy. The consumers were aware of the timing of finishing using an appliance, and the action rate increased by using the interface. In addition, consumers were temporarily aware of their power-off actions. On the other hand, they did not come up with their own energy-saving strategy, as they became unaware of their actions some time after finishing using the interface. Once an energy-saving strategy is created, consumers' consciousness does not change in time. Therefore, a method for preventing consumers' consciousness from decreasing after a lapse of time is necessary. In order to find such a method, we focus on the questions whose scores are higher after an interval than in the pre-period. There are 26 (4 appliances $\times$ 3 waste times $\times$ 10 participants) out of 120 questions whose scores are high. If we classified the 26 questions by participant, the increase in the action rate is higher than in the case of the other questions. Therefore, the more consumers take action, the more difficult it is for their consciousness to decrease. Strictly speaking, the increases of their action feeling affect their consciousness. Accordingly, it is assumed that if their actions are emphasized consumers, consumers can be assisted in creating energy-saving strategies. The main role of the interface used in this experiment is to let consumers know about the best timing for their actions before they actually perform them. In other words, the interface does not support the consumers after taking action. We propose informing the consumers about

the action after it has been taken, for emphasize. It is expected that emphasizing post-factum will prevent the consciousness from decreasing, and work toward the creation on an energy-saving strategy. This method will be introduced in the experiment period because the consciousness is at its highest now. It should be introduced after consumers get used to the interface used in this study to prevent confusion.

In this paper, we used the cue offering interface in order to investigate the effect of offering cues for energy-saving strategies. If the cue offering interface is introduced into the real world, we need to consider the usability of the interface and energy consumption for the use of the interface. For example, if we focus on the usability, we need to consider the studies to develop wireless sensor systems or the studies to detect and classify human behaviors by cameras. The cue offering interface consists of the wired sensors, however a system with wireless sensors can exceed the place limitation because it is not necessary to closely install the sensors and the controller (PC) for their communication. Bhattacharjee et al. develop a wireless sensing system for environmental monitoring [13]. This system observes environment for detecting environmentally hazardous. We can use the sensing data as the information for offering cues. The cue offering interface adapts lots of kinds of appliances. When the system detects and classifies human behaviors by cameras, we can construct the system which consists of contactless sensors [14]. A system with contactless sensors can install into the living space of users without disturbing users’ lives. On the other hand, if we focus on the energy consumption of the interface, we can improve the energy efficiency of the interface by studies with the aim of the improvement for energy efficiency of sensor systems for using in a long term. Samanta et al. propose the algorithm to expect human behavior for improving the energy efficiency of sensor systems [15]. When we adapt the algorithm for the cue offering interface, we can reduce the sensing time and its energy consumption. Thus, when we introduce the cue offering interface in the real world, we have to consider these points.

VI. CONCLUSION

In this study, we focused on the power-off actions which are included in the energy-saving behavior in order to contribute to solving the energy problem. In addition, we designed an interface which offers cues in order to increase the consciousness of consumers by taking action.

We conducted a 2-week experiment using the interface. The results suggested that offering cues increases the number of the power-off actions. In addition, it is suggested that if the change in the action rate is high in the experiment period, it is easier to maintain the consumers' consciousness after a lapse of time. In order to prevent the consciousness from decreasing, we proposed a method which emphasizes taking action post-factum. Further studies are needed in order to examine differences depending on the appliance, which have not been selected in this study.

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