Experimental Study on Display of Energy-Related Information in Smart Homes and Electric Vehicles

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ABSTRACT

Environmental pollution and electrical power shortages are serious worldwide issues. Since private households clearly constitute a main energy consumer, the environment can be positively affected if home energy consumption is reduced. We are developing a prototype smart home that offers a smart quality of life (QOL) to its residents and reduces both CO_2 emissions and energy consumption. An important issue toward achieving this aim is how to show energy-related information to residents. Last year, we focused on QOL and experimentally clarified where and how to display such information in a smart home. In this article, we describe our new experiment that clarifies how to display energy-related information and controls for home appliances in smart homes and electric vehicles (EVs).

Keywords: smart home, energy saving, user interface, information presentation

INTRODUCTION

Environmental pollution and electric power shortages are serious worldwide issues. Since private households clearly constitute one main energy consumer (Bertoldi and Atanasiu, 2009), we expect positive environmental effects if home energy consumption is reduced (Kofler and Reinisch, 2012). The deployment of automation technologies in the home offers several attractive benefits, including most prominently increased energy efficiency, improved residential comfort, and peace of mind. We are developing a prototype smart home that offers a smart quality of life (QOL) to its residents and reduces both CO_2 emissions and energy consumption. An important issue toward achieving this aim is how to show energy-related information to its residents. Our platform consists of two smart homes in Saitama City in Japan (Honda Motor Co., Ltd, 2012). A family lives in one of them, and the other is open to visitors (see Figure 1). In our interviews with family members, they showed a strong desire to know energy-related information in real time. Based on those results, we experimentally clarified where and how to display such information in a smart home last year (Ito and Ohkura, 2013). In this article, we describe our experiment that clarified how to display energy-related information and controls for home appliances in smart homes and electric vehicles (EVs), which we employed because we believe that mobility is necessary for modern lifestyles.

Figure. 1 Smart home for visitors

PREVIOUS EXPERIMENT

First, we experimentally clarified the preferred locations and energy-related information in a smart home (Ito and Ohkura, 2013) and obtained the following findings:

- All candidate locations were considered necessary, especially the wall next to the refrigerator.
- All energy-related information was considered necessary, and information that provides users an actual feel for energy savings, such as overall power consumption and utility cost, are especially demanded.
- The required information depends on the location. For example, participants want to reduce the number of energy-related information at locations where monitors are small and require the temperature of the hot-water system if the location is near the kitchen.

NEW EXPERIMENT

Method

Based on our previous experiment results, we designed and performed a new experiment. Since mobility is important for the QOL of smart homes, we added an EV dashboard as a location candidate as well as interfaces for the controls for such electric devices as air conditioners for the same reason. This experiment clarified the locations and the contents of displayed energy-related information and controls for home appliances demanded in smart homes and EVs. We displayed the energy-related information and home appliance controls on wall monitors next to the refrigerator in a smart home and on monitors on the EV dashboard (see Figure 2 and 3). Participants evaluated the degree of the necessity for each piece of information and control and decided the best layout for each location.

Figure. 2 Wall monitor next to refrigerator

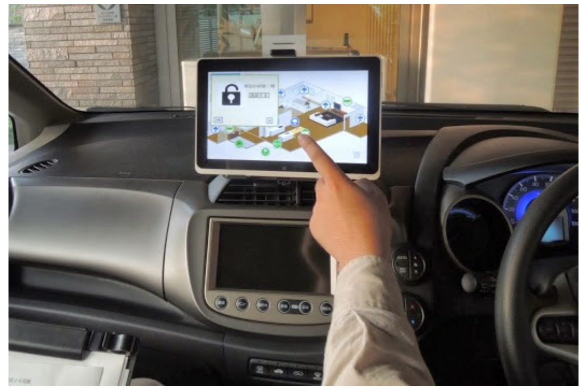

Figure. 3 Monitor on EV dashboard

We employed the following six device candidates to be controlled and twelve candidates of energy-related information (see Figure 4):

1. Lock front door
2. Open/close shutters
3. Open/close garage gate
4. Wash and fill bathtub
5. Switch lights on or off
6. Switch air conditioning on or off

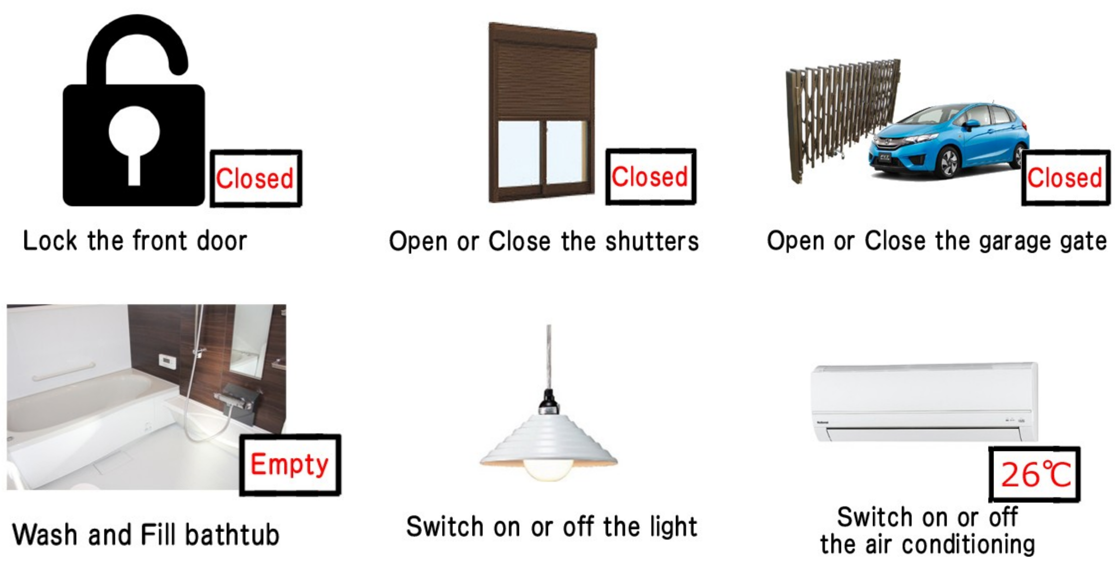

Figure. 4 Device candidates to be controlled

The following are the energy-related information candidates (see Figure 5):

A. Amount of electricity generated by solar power
B. Amount of electricity and heat generated by cogeneration
C. Amount of total electricity generated
D. Amount of consumed commercial electric power
E. Overall power consumption
F. Percentage of power consumption covered by home electricity generation
G. Utility cost

H. Electric power-selling rate
I. CO_2 emission reductions
J. Temperature of hot-water system
K. Remaining EV car battery level
L. Remaining home battery level

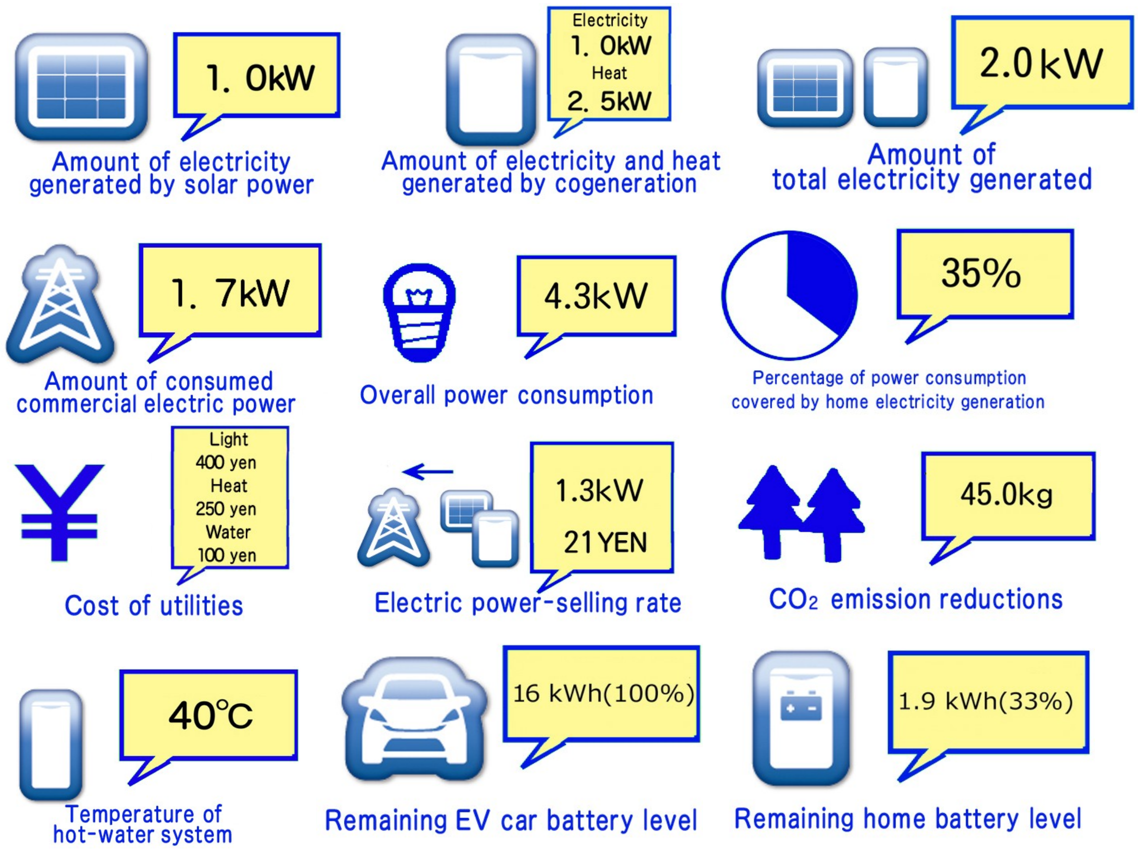

Figure. 5 Candidates of energy-related information

The following are the display layouts (see Figure 6, 7 and 8):

1. Controls and Information displayed on table and run in full screen.
2. Controls and Information displayed on table and run in pop-up window.
3. Controls and Information displayed on smart home's layout chart and run in window.

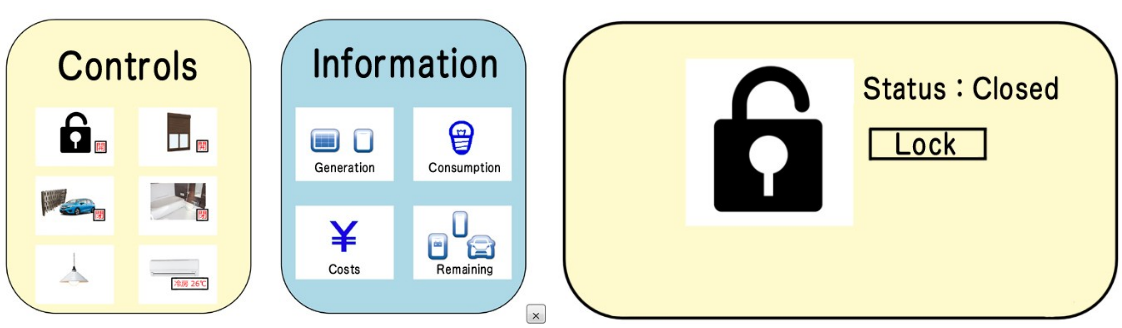

Figure. 6 Layout 1

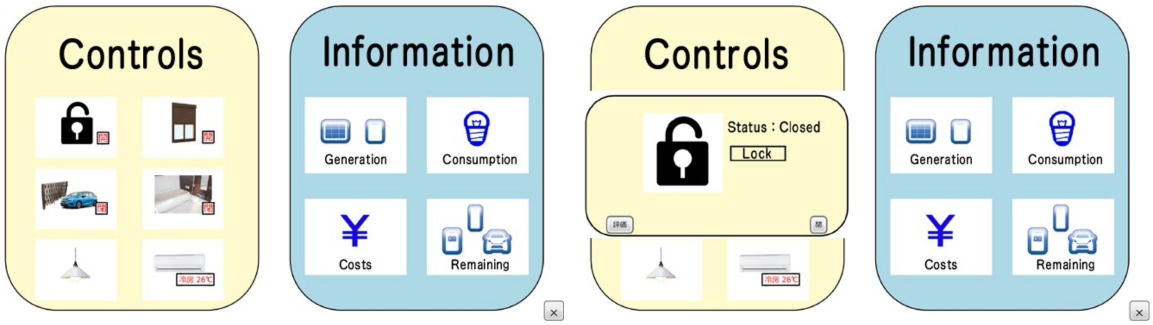

Figure. 7 Layout 2

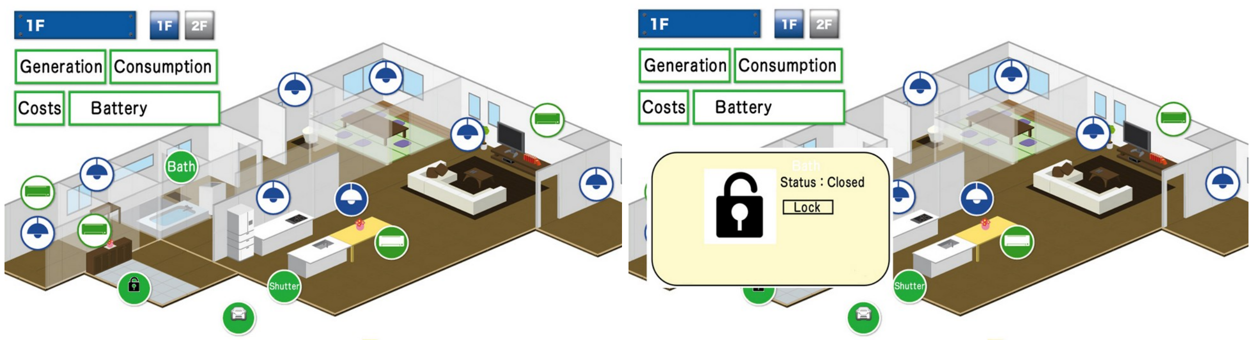

Figure. 8 Layout 3

The layouts were displayed on the monitor. We explained all controls and information to participants. After the explanations, participants evaluated the degree of necessity of the controls and information (see Figure 9). We also showed other layouts from which they chose the best at the location. After that, participants moved to another location and evaluated again.

Figure. 9 Experimental landscape in EV

Results

We performed our experiment with 56 participants who received explanations about the smart home before the experiment. Fig. 10 shows our preferred layout results. The best layout was different between the wall next to the refrigerator and EV dashboard. Layout 3 was judged best on the wall next to the refrigerator. On the other hand, Layouts 1 and 3 were judged best on the EV dashboard because its monitor was bigger than the wall monitor next to the refrigerator. In addition, participants could closely examine the wall monitor next to the refrigerator. We compared the results among occupation of participants, but we found the same tendency (see Figure 11).

Figure 12 shows the comparison results for the two locations about the degrees of necessity. We normalized them because the criterion for assessment differed among participants. The degrees of necessity for the controls on the EV dashboard were higher than on the wall next to the refrigerator. On the other hand, the degrees of necessity for the information on the wall next to the refrigerator were higher than on the EV dashboard. Most energy-related information was judged unnecessary. In addition, overall power consumption and cost of utilities were judged as necessary as the wall monitor next to the refrigerator. Since they just thought about costs, they only based their judgments on economic reasons. It is because the participants don't live in smart homes. Since remaining EV car battery level and remaining home battery level concerned indispensable features, the participants deemed them necessary.

Figure 13 shows the comparison results for two locations and gender about the degrees of necessity. In particular, women judged the following as necessary: open/close the shutters, electric power-selling rate, temperature of hot-water system, and remaining EV car battery level. Women strongly demand information displays about security, money, and domestic duties.

Figure 14 shows the comparison results of two locations and jobs about the degrees of necessity. We divided the results into students and non-students. It is because we considered that the demands differ between student and non-student. Students judged the following as necessary: wash and fill bathtub and overall power consumption. On the other hand, non-students judged these as necessary: open/close the shutters, electric power-selling rate, CO2 emission reductions, and temperature of hot-water system. Non-students strongly want to contribute to society.

Our participants made the following opinions in the questionnaires:

- I want to compare the energy-related information of my home and prefectural and national averages.
- I want Home Energy Management System (HEMS) to suggest the best way to generate and use energy.
- I want to know whether there is somebody in the house.
- I want to check on pets and my elderly parents.
- I want one switch that easily clicks off everything in my house.

From these results, we choose information to match users.

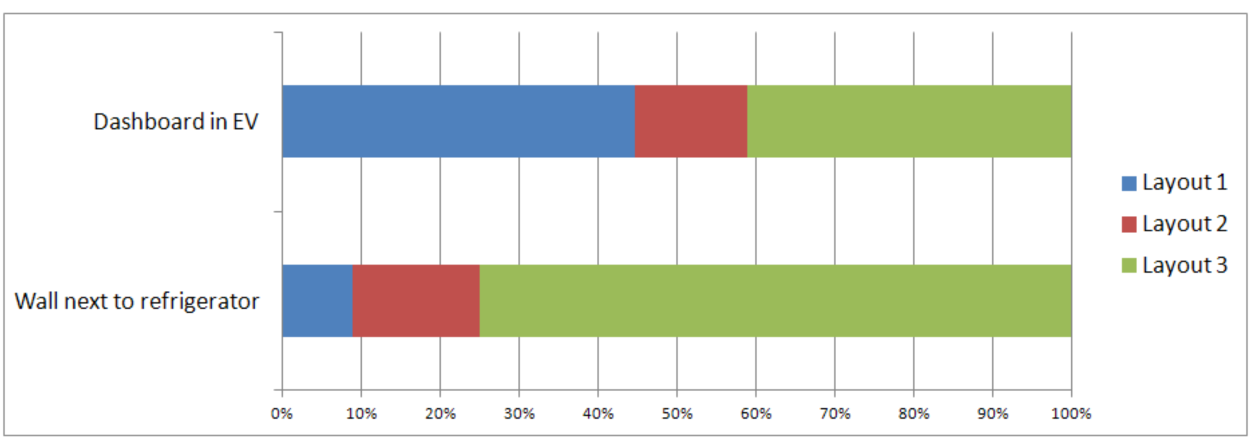

Figure 10 Results for preferred layout

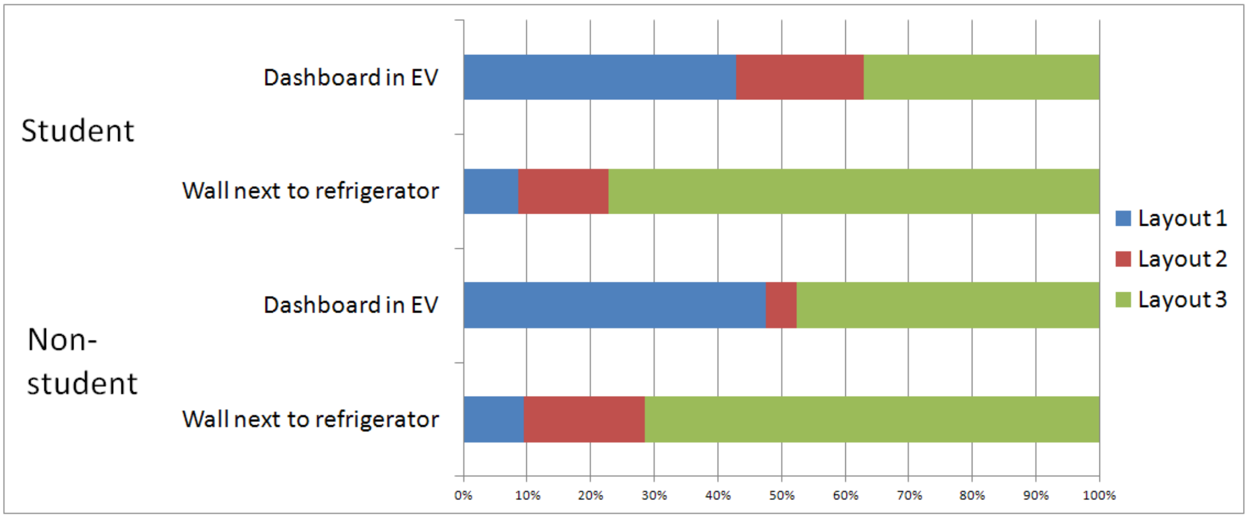

Figure. 11 Comparison results of occupation about preferred layout

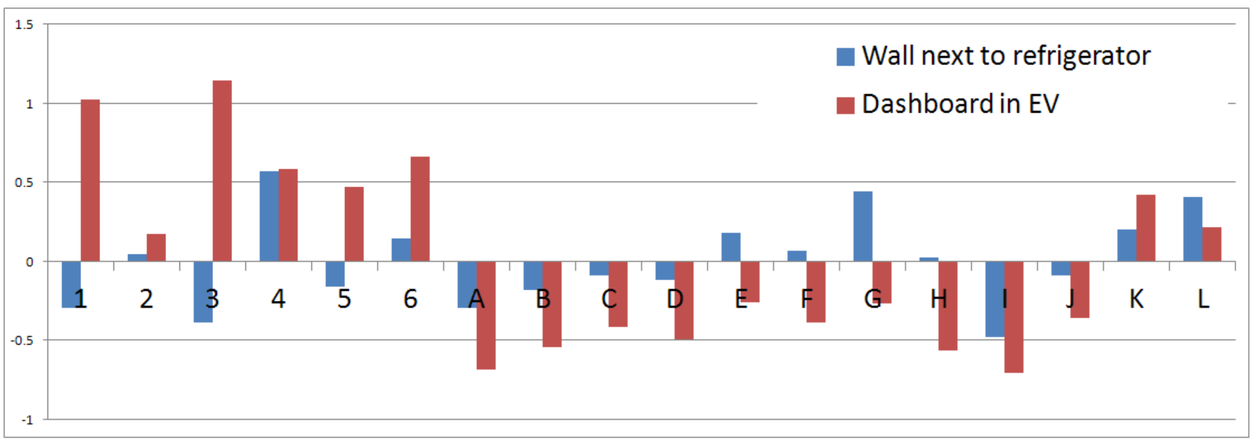

Fig 12 Comparison results of two locations about degrees of necessity

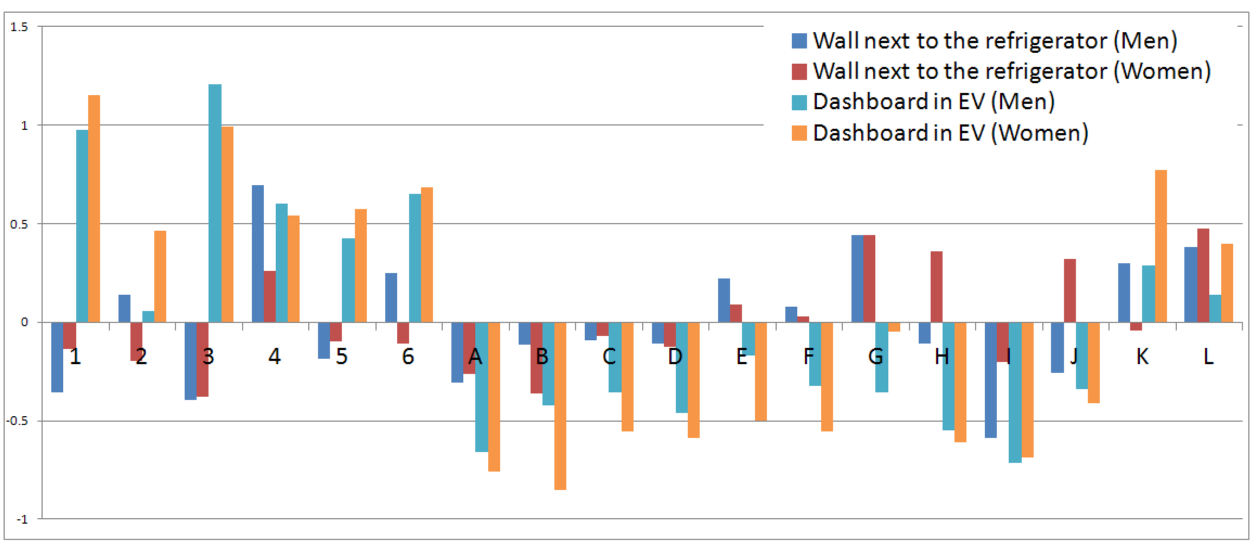

Figure. 13 Comparison results of two locations and gender about degrees of necessity

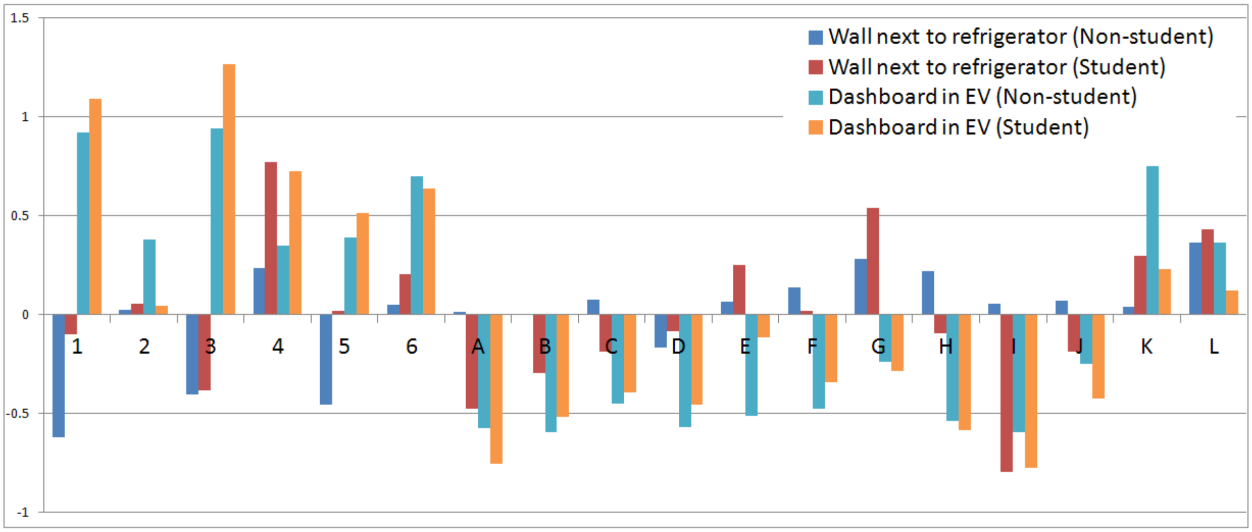

Figure. 14 Comparison results of two locations and jobs about degrees of necessity

CONCLUSIONS

We focused on quality of life (QOL) and experimentally clarified how to display energy-related information and controls for home appliances in smart homes and in electric vehicles (EV). We obtained the following findings:

- Participants made different demands between smart homes and EV. For example, a simple display was required in EV, and controls were judged more necessary than information in EV.
- Most energy-related information was judged unnecessary, but energy-related information associated with economics was judged necessary. Since our participants don't live in smart homes, their judgments were based on financial reasons.
- The controls and information must be matched to different demands based on gender or jobs.

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REFERENCES

Bertoldi, P. and Atanasiu, B. (2009), *"Electricity Consumption and Efficiency Trends in European Union."* in: Status Report, Institute for Energy, Joint Research Center-European Commission

Kofler, M. J., Reinisch, and C., Kastner, W. (2012), *"A semantic representation of energy-related information in future smart homes."* in: Energy and Buildings, Vol. 47, pp. 169-179

Ito, K. and Ohkura, M., (2013), "*Experimental Study on Display of Energy-related Information in Smart Homes Using Virtual Reality*" in: Distributed, Ambient, and Pervasive Interactions, Lecture Notes in Computer Science, Vol. 8028, pp. 294-301

Honda Motor Co., Ltd (2012), *A New Safe and Secure Lifestyle with Lower CO_2 Emissions: The Honda Smart Home System.* The Honda Motor Website:
http://world.honda.com/environment/face/2012/case16/episode/episode01.html

Randolph, J. (2012), *Honda "smart home" showcases off-the-grid energy solutions.* The gizmag website:
http://www.gizmag.com/honda-demonstration-smart-home/22328/