



**HAL**  
open science

# Design of Incentive & Intelligent User Interfaces (I2UI) for behavior change: energy management for smart homes as case study

Yidong Huang

► **To cite this version:**

Yidong Huang. Design of Incentive & Intelligent User Interfaces (I2UI) for behavior change: energy management for smart homes as case study. IHM'23 - 34e Conférence Internationale Francophone sur l'Interaction Humain-Machine, AFIHM; Université de Technologie de Troyes, Apr 2023, Troyes, France. hal-04042331

**HAL Id: hal-04042331**

**<https://hal.science/hal-04042331>**

Submitted on 23 Mar 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

---

# Design of Incentive & Intelligent User Interfaces ( $I^2UI$ ) for behavior change : energy management for smart homes as case study

*Interfaces utilisateur incitatives et intelligentes ( $I^2UI$ ) pour le changement de comportement : cas de la gestion de l'énergie pour les maisons intelligentes*

**Yidong HUANG**

Univ. Grenoble Alpes

Grenoble, France

Yidong.Huang@univ-grenoble-alpes.fr

## ABSTRACT

Targeting home energy management, we investigate Incentive & Intelligent UIs ( $I^2UI$ ) designed to help users (1) voluntarily change their behavior to reduce and (2) optimise energy use. Thanks to this combination, we envision human-system cooperation through Co-learning and Co-decision as an approach to better engage and support users throughout the behaviour change process.

## CCS CONCEPTS

• **Human-centered computing** → **HCI theory, concepts and models.**

## KEYWORDS

Incentive & Intelligent User Interface, Persuasion, Human AI Interaction, Energy Management.

---

*IHM'23, April 03–07, 2023, Troyes, France*

© 2023 Copyright held by the owner/author(s).

This is the author's version of the work. It is posted here for your personal use. Not for redistribution. The definitive Version of Record was published in *IHM'23 : Extended Proceedings of 34<sup>ème</sup> conférence Francophone sur l'Interaction Humain-Machine, April 03–07, 2023, Troyes, France.*

### **RÉSUMÉ**

*Avec la gestion de l'énergie comme domaine d'application, cette thèse étudie les interfaces incitatives & intelligentes (I<sup>2</sup>UI) conçues pour aider des occupants à (1) réduire et (2) optimiser l'usage de l'énergie. Par cette approche conjointe, nous visons une coopération humain-système par du co-apprentissage et de la co-décision pour mieux engager et accompagner les utilisateurs dans le changement de comportement.*

### **MOTS CLÉS**

*Interface Incitative & Intelligente, Persuasion, Interaction Homme-IA, Système de Gestion de l'Énergie.*

### **INTRODUCTION**

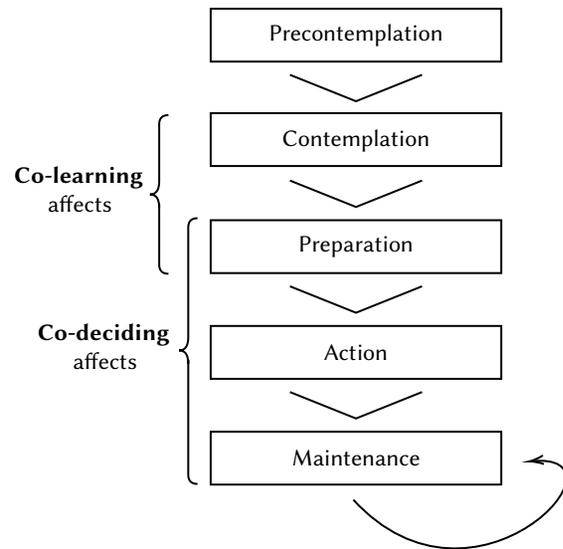
Incentive User Interfaces (UIs) are designed to assist users in a voluntary behaviour change process [6, 13, 14, 27]. On this research, the reduction of energy consumption is one of the most studied application domains [9, 24]. Intelligent UIs are designed to assist humans in diverse use scenarios[17, 32], including how to save energy at home[7, 22]. However, each approach faces challenges and limitations that hinder its energy-saving potential. User's lack of knowledge and capacity can limit the effectiveness of Incentive UIs, particularly in the long term[2, 13, 23, 37]. As for Intelligent UIs, a lack of intelligibility undermines the human-system cooperation[35, 36].

Targeting home energy management systems, our research question is: How can Incentive UIs be designed leveraging the power of Intelligent UIs regarding energy use behaviors. Thanks to this combination, we envision human-system cooperation through Co-learning and Co-decision as an approach to better engage and support users throughout the behaviour change process. In the following sections, we detail the context of our research and its motivation, as well as our research approach, research methodology and expected contributions.

### **RESEARCH CONTEXT AND MOTIVATION**

Household energy consumption stands for 28% of energy consumption in the EU, 2020[5]. Despite improved appliance efficiency over the past decades, consumption behavior remains a major factor on energy use[11, 12, 12, 16, 19, 38]. To achieve emissions reductions and climate goals[4], energy sobriety in everyday activity is crucial.

Incentive UIs can help to raise awareness of energy consumption and assist users to adopt more energy-sober behaviours[9, 10, 13]. However, fully understanding the energy impact of one's activity can be a daunting task for average consumers[1, 2, 21, 28, 36, 37]. Users' limited capacity may in turn limit the effectiveness of Incentive UIs as knowledge and skills are a key part in many behaviour change models[27], of which many Incentive UIs are built upon. In addition, current Incentive UI designs overlook habitual behavior and may lack long-term efficacy[13, 27].



**Figure 1: Co-learning and Co-deciding in TransTheoretical Model(TTM)**

Intelligent UIs present new opportunities and challenges for home energy management systems. With learning algorithms, energy-saving possibilities become accessible to a broader audience, reducing user effort, knowledge and skill requirements. However, as intelligent systems exhibit substantial differences from conventional systems, HCI researchers face a new set of challenges when it comes to interaction designs for or powered by learning algorithms[17].

Existing home energy management systems using intelligent systems struggle to consider complex contextual information, leading to user dissatisfaction[36, 37]. Such an issues are often neglected in UI and system design, making it difficult for users to improve their experience[36]. A lack of intelligibility can exacerbate user frustration and hinder system’s credibility[35, 36].

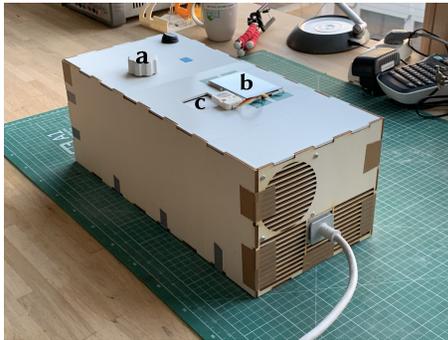
The issues mentioned in current research suggest a combined approach for sustainable behavior change and reducing energy consumption. However, few studies exist on this approach, hence our motivation. We envision a smart home energy management system using *I<sup>2</sup>UI* to engage and support behavior change through human-system cooperation.

### RESEARCH APPROACH

We aim to combine Incentive UI and Intelligent UI into a digital partner while users remain in control over their home, encouraging human-system cooperation towards the common goal of optimizing and reducing energy consumption at home. Human-system cooperation should leverage user engagement and support of a sustainable change towards energy sobriety.

Particularly, our originality, we study two aspects of human-system cooperation: **Co-learning** and **Co-deciding**, related to behaviour change techniques(BCT) [23] found adequate for the context of home energy management [30] to improve knowledge and skills (i.e., MoA: Mechanisms of Action[23]) about energy consumption, thus to facilitate behaviour change.

In **Co-learning**, the user and the system construct a common model of energy consumption at home through interactive annotation, which involves the self-monitor BCT. Users are not always aware of their behaviours as they are not always rational and intentional[8, 12, 16, 19, 25, 26, 29, 31, 38]. energy is intangible thus is hard to keep track of one’s consumption[10]. Interactive annotation on energy consumption data is shown to provoke deep self-reflection[15]. Co-learning leverages the power of sensors and intelligent systems to record and organise events that may have been overlooked by the user. Through interactive annotation, users can be reminded of these events and provide additional key data such as motivations and intentions that are unobtainable through sensors. In Co-learning, such a BCT can be better supported, thus increase user’s awareness and understanding of the cause-effect relation in everyday activity, evoking MoAs regarding knowledge, beliefs and attention to facilitate the behaviour change process[3, 27]. Additionally, Co-learning addresses the challenge of data collection as users can provide valuable contextual data in interactive annotation.



**Figure 2: The “Feel heal? Feel-it” prototype thermostat. On the prototype: (a) a rotating knob/button, (b) a screen, (c) a variable temperature Peltier module. Before use, users are guided to complete a calibration process to fine tune the thermal stimulus. The prototype adjust it’s thermal stimulus based on a user’s average fingertip temperature, the room temperature as well as the user’s current thermal sensation. After each adjustment, the prototype provides a thermal stimulus reflecting the estimated level of comfort associated with the new setpoint through the Peltier module, allowing users to feel the thermal stimulus through touch and decide if further adjustment is necessary.**

In **Co-deciding**, the system and the user cooperatively decide on action plans to save energy based on the common model constructed in Co-learning. Users keep control of the final decision over what action to perform. Research works have previously demonstrated that smart systems can compensate for user’s lack of capacity and knowledge to act on their intention of behaviour change[1, 18, 28, 36]. But this approach can suffer from the lack of long term effectiveness if users blindly adopt system’s suggestions without understanding them[27, 36, 37]. As Co-learning helps the user and the system builds a common model of energy use, it serves as a scaffolding to better support BCTs involved in Co-deciding. Techniques such as goal setting and action planning may become more effective as the knowledge accumulated in Co-learning can help the user better understand the system’s propositions.

### RESEARCH PLAN AND EXPECTED CONTRIBUTIONS

This doctoral research is planned in the following way.

**Step 1:** Case study: the use and the design of thermostat UI. The case study provides us an opportunity to gain insight on simultaneously one of the most energy consuming end-uses in homes[5] while also being heavily influence by inhabitants’ habits, preferences and believes[25, 29, 33]: space heating. We explore design alternatives to (a.) improve the learnability of the cause-consequence relationship between setting a setpoint and the eventual thermal sensation, and (b.) facilitate the process of choosing a setpoint that is coherent with the actual thermal comfort need.

**Step 2:** Generalisation of findings in step 1 to other everyday activities in the task of integrative annotation in order to achieve optimal Co-learning.

**Step 3:** The study of optimal Co-deciding to effectively and sustainably incited users towards a more efficient energy consumption behaviour at home following Co-learning.

For each step, we adopt the same research methodology: under one or several identified theoretical frameworks(e.g. [27, 30, 33, 34]), we develop and evaluate novel interaction designs regarding it’s effectiveness in Co-learning, Co-deciding, or both at the same time. The expected contributions of our research include new interaction techniques for *I<sup>2</sup>UI* and conceptual contributions of *I<sup>2</sup>UI* design framework(i.e. Co-learning and Co-deciding).

### CURRENT STATE OF WORK & PROSPECTIVE

We are currently at the step 1 of our research plan. We proposed new interaction design principles called “Feelback” and “Feelforward” that rely on sensory modalities to reflect and guide a user’s action as our fist conceptual contribution, enriching Norman’s feedback and feedforward design principles.

Current thermostat design lacks the immediate feedback[20, 25, 33] in the appropriate modality to allow users to associate an particular setting with a certain level of comfort, resulting a low learnability of the action-consequence relation in regards to comfort. “Feelback” and “Feelforward” are informed by the behaviour model proposed in [33] and the “interaction frogger” design framework[34]. The

interaction frogger framework[34] suggests that, to improve the learnability, a interaction design with a stronger coupling between action and function is required, namely regarding the aspects of time and modality. Therefore, in the case of thermostat, we developed the “Feel heat? feel-it!”, a proof-of-concept prototype thermostat (Figure 2) which provides a immediate thermal stimulus through touch after each adjustment. The prototype illustrates the new interaction techniques which can be developed using these new principles. A between subject design is used to evaluate the new interaction technique in comparison with conventional thermostat interaction design. We hypothesise the new interaction technique can help users to better anticipate the result of each setpoint change, therefor making the adjustment more accurate and more efficient. Initial test results show that our new thermostat design allows users to more easily reflect on their usual habit of heating in regard to their actual thermal comfort needs and may prevent over-adjustments of the setpoint. Future research is needed to determine the long-term efficacy of our new thermostat interaction design. We also plan to generalise “feelback” and “feelforward” to other daily activities to increase learnability and aid users in the interactive annotation, particularly for activities where consumption occurs posteriorly(e.g. using a washing machine or a dishwasher) as the next step of our research work in regards to Co-learning. Additionally, “feelforward” will be further investigated in the context of co-deciding.

## CONCLUSION

In this research work we aim to combine Intelligent UI with Incentive UI to create *I*<sup>2</sup>UI with the goal of supporting users through out the behaviour change process towards energy sober consumption behaviour thus cooperatively reducing the energy consumption at home. Our research addresses the knowledge gap regarding the use of *I*<sup>2</sup>UI to support behaviour change. Based on the hypothesized links between BCTs and MoAs, we propose designs to support the human-system cooperation in the form of “Co-learning” and “Co-deciding”: two scaffolds to put a set of BTCs in-place in order to act on a particular set of MoAs [3].

We proposed the “feelback” and “feelforward” design principles to improve the learnability of the cause-consequence relation between setpoint and comfort in thermostat design, and plan to apply them in other activities in the interactive annotation task for Co-learning. Our research has implications beyond smart home energy management, as it provides a new perspective for Digital Behaviour Change Intervention (DBCI) which has many health-related applications such as food consumption, physical activity, and well-being.

## ACKNOWLEDGMENTS

This research is financed by the ANR project LearningHome(ANR-21-CE22-0017).

## REFERENCES

- [1] Alper T. Alan, Mike Shann, Enrico Costanza, Sarvapali D. Ramchurn, and Sven Seuken. 2016. It is too Hot: An In-Situ Study of Three Designs for Heating. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, San Jose California USA, 5262–5273. <https://doi.org/10.1145/2858036.2858222>
- [2] Dirk Brounen, Nils Kok, and John M. Quigley. 2013. Energy literacy, awareness, and conservation behavior of residential households. *Energy Economics* 38 (July 2013), 42–50. <https://doi.org/10.1016/j.eneco.2013.02.008>
- [3] Rachel N Carey, Lauren E Connell, Marie Johnston, Alexander J Rothman, Marijn de Bruin, Michael P Kelly, and Susan Michie. 2018. Behavior Change Techniques and Their Mechanisms of Action: A Synthesis of Links Described in Published Intervention Literature. *Annals of Behavioral Medicine* (Oct. 2018). <https://doi.org/10.1093/abm/kay078>
- [4] European Commission. 2020. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit of our people. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0562>
- [5] European Commission. Statistical Office of the European Union. 2020. *Harmonised European Time Use Surveys: 2018 guidelines : re edition, 2020 edition*. Publications Office, LU. <https://data.europa.eu/doi/10.2785/160444>
- [6] Brian Jeffrey Fogg. [n. d.]. Behavior Model. <https://behaviormodel.org/>
- [7] Rebecca Ford, Marco Pritoni, Angela Sanguinetti, and Beth Karlin. 2017. Categories and functionality of smart home technology for energy management. *Building and Environment* 123 (Oct. 2017), 543–554. <https://doi.org/10.1016/j.buildenv.2017.07.020>
- [8] Elisha R. Frederiks, Karen Stenner, and Elizabeth V. Hobman. 2015. Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. *Renewable and Sustainable Energy Reviews* 41 (Jan. 2015), 1385–1394. <https://doi.org/10.1016/j.rser.2014.09.026>
- [9] Jon Froehlich. 2009. Promoting Energy Efficient Behaviors in the Home through Feedback: The Role of Human-Computer Interaction. (2009), 11.
- [10] Jon Froehlich, Leah Findlater, and James Landay. 2010. The design of eco-feedback technology. In *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10*. ACM Press, Atlanta, Georgia, USA, 1999. <https://doi.org/10.1145/1753326.1753629>
- [11] Zachary M. Gill, Michael J. Tierney, Ian M. Pegg, and Neil Allan. 2010. Low-energy dwellings: the contribution of behaviours to actual performance. *Building Research & Information* 38, 5 (Oct. 2010), 491–508. <https://doi.org/10.1080/09613218.2010.505371>
- [12] Kirsten Gram-Hanssen. 2013. Efficient technologies or user behaviour, which is the more important when reducing households' energy consumption? *Energy Efficiency* 6, 3 (Aug. 2013), 447–457. <https://doi.org/10.1007/s12053-012-9184-4>
- [13] Juho Hamari, Jonna Koivisto, and Tuomas Pakkanen. 2014. Do Persuasive Technologies Persuade? - A Review of Empirical Studies. In *Persuasive Technology*, David Hutchison, Takeo Kanade, Josef Kittler, Jon M. Kleinberg, Alfred Kobsa, Friedemann Mattern, John C. Mitchell, Moni Naor, Oscar Nierstrasz, C. Pandu Rangan, Bernhard Steffen, Demetri Terzopoulos, Doug Tygar, Gerhard Weikum, Anna Spagnolli, Luca Chittaro, and Luciano Gamberini (Eds.). Vol. 8462. Springer International Publishing, Cham, 118–136. [https://doi.org/10.1007/978-3-319-07127-5\\_11](https://doi.org/10.1007/978-3-319-07127-5_11) Series Title: Lecture Notes in Computer Science.
- [14] Marja Harjumaa and Harri Oinas-Kukkonen. 2007. Persuasion Theories and IT Design. In *Persuasive Technology*, David Hutchison, Takeo Kanade, Josef Kittler, Jon M. Kleinberg, Friedemann Mattern, John C. Mitchell, Moni Naor, Oscar Nierstrasz, C. Pandu Rangan, Bernhard Steffen, Madhu Sudan, Demetri Terzopoulos, Doug Tygar, Moshe Y. Vardi, Gerhard Weikum, Yvonne de Kort, Wijnand IJsselstein, Cees Midden, Berry Eggen, and B. J. Fogg (Eds.). Vol. 4744. Springer Berlin

- Heidelberg, Berlin, Heidelberg, 311–314. [https://doi.org/10.1007/978-3-540-77006-0\\_37](https://doi.org/10.1007/978-3-540-77006-0_37) Series Title: Lecture Notes in Computer Science.
- [15] Melanie R. Herrmann, Enrico Costanza, Duncan P. Brumby, Tim Harries, Maria das Graças Brightwell, Sarvapali Ramchurn, and Nicholas R. Jennings. 2021. Exploring domestic energy consumption feedback through interactive annotation. *Energy Efficiency* 14, 8 (Dec. 2021), 90. <https://doi.org/10.1007/s12053-021-09999-0>
- [16] Guy Hitchcock. 1993. An integrated framework for energy use and behaviour in the domestic sector. *Energy and Buildings* 20, 2 (Jan. 1993), 151–157. [https://doi.org/10.1016/0378-7788\(93\)90006-G](https://doi.org/10.1016/0378-7788(93)90006-G)
- [17] Anthony Jameson and John Riedl. 2011. Introduction to the Transactions on Interactive Intelligent Systems. *ACM Transactions on Interactive Intelligent Systems* 1, 1 (Oct. 2011), 1–6. <https://doi.org/10.1145/2030365.2030366>
- [18] Rikke Hagensby Jensen, Jesper Kjeldskov, and Mikael B. Skov. 2016. HeatDial: Beyond User Scheduling in Eco-Interaction. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*. ACM, Gothenburg Sweden, 1–10. <https://doi.org/10.1145/2971485.2971525>
- [19] Rikke Hagensby Jensen, Jesper Kjeldskov, and Mikael B. Skov. 2018. Assisted Shifting of Electricity Use: A Long-Term Study of Managing Residential Heating. *ACM Transactions on Computer-Human Interaction* 25, 5 (Oct. 2018), 1–33. <https://doi.org/10.1145/3210310>
- [20] Sami Karjalainen. 2007. *The characteristics of usable room temperature control*. Ph.D. Dissertation. VTT, Espoo. ISBN: 9789513870591 9789513870607 OCLC: 231173422.
- [21] Ana Martins, Mara Madaleno, and Marta Ferreira Dias. 2020. Energy literacy: What is out there to know? *Energy Reports* 6 (Feb. 2020), 454–459. <https://doi.org/10.1016/j.egy.2019.09.007>
- [22] Claire McIlvennie, Angela Sanguinetti, and Marco Pritoni. 2020. Of impacts, agents, and functions: An interdisciplinary meta-review of smart home energy management systems research. *Energy Research & Social Science* 68 (Oct. 2020), 101555. <https://doi.org/10.1016/j.erss.2020.101555>
- [23] Susan Michie, Maartje M van Stralen, and Robert West. 2011. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science* 6, 1 (Dec. 2011), 42. <https://doi.org/10.1186/1748-5908-6-42> Number: 1.
- [24] Van Nguyen, Yann Laurillau, Gaëlle Calvary, and Joëlle Coutaz. 2021. Persuasive Systems for Energy: Cartography of Design Spaces and Proposition of the UP+ Framework. *Journal d'Interaction Personne-Système* Volume 9, Number 1, Special..., Special Issue... (Jan. 2021), 7100. <https://doi.org/10.46298/jips.7100> Number: Special Issue...
- [25] Therese Peffer, Marco Pritoni, Alan Meier, Cecilia Aragon, and Daniel Perry. 2011. How people use thermostats in homes: A review. *Building and Environment* 46, 12 (Dec. 2011), 2529–2541. <https://doi.org/10.1016/j.buildenv.2011.06.002> Number: 12.
- [26] James Pierce, Diane J. Schiano, and Eric Paulos. 2010. Home, habits, and energy: examining domestic interactions and energy consumption. In *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10*. ACM Press, Atlanta, Georgia, USA, 1985. <https://doi.org/10.1145/1753326.1753627>
- [27] Charlie Pinder, Jo Vermeulen, Benjamin R. Cowan, and Russell Beale. 2018. Digital Behaviour Change Interventions to Break and Form Habits. *ACM Transactions on Computer-Human Interaction* 25, 3 (June 2018), 1–66. <https://doi.org/10.1145/3196830> Number: 3.
- [28] Devika Pisharoty, Rayoung Yang, Mark W. Newman, and Kamin Whitehouse. 2015. ThermoCoach: Reducing Home Energy Consumption with Personalized Thermostat Recommendations. In *Proceedings of the 2nd ACM International Conference on Embedded Systems for Energy-Efficient Built Environments*. ACM, Seoul South Korea, 201–210. <https://doi.org/10.1145/2821650.2821671>
- [29] Kirsten M.A. Revell and Neville A. Stanton. 2014. Case studies of mental models in home heat control: Searching for feedback, valve, timer and switch theories. *Applied Ergonomics* 45, 3 (May 2014), 363–378. <https://doi.org/10.1016/j.apergo>

- 2013.05.001
- [30] Angela Sanguinetti, Kelsea Dombrovski, and Suhaila Sikand. 2018. Information, timing, and display: A design-behavior framework for improving the effectiveness of eco-feedback. *Energy Research & Social Science* 39 (May 2018), 55–68. <https://doi.org/10.1016/j.erss.2017.10.001>
  - [31] Linda Steg. 2008. Promoting household energy conservation. *Energy Policy* 36, 12 (Dec. 2008), 4449–4453. <https://doi.org/10.1016/j.enpol.2008.09.027>
  - [32] Niels van Berkel, Mikael B. Skov, and Jesper Kjeldskov. 2021. Human-AI interaction: intermittent, continuous, and proactive. *Interactions* 28, 6 (Nov. 2021), 67–71. <https://doi.org/10.1145/3486941>
  - [33] Raino Vastamäki, Irmeli Sinkkonen, and Cecilia Leinonen. 2005. A behavioural model of temperature controller usage and energy saving. *Personal and Ubiquitous Computing* 9, 4 (July 2005), 250–259. <https://doi.org/10.1007/s00779-004-0326-3> Number: 4.
  - [34] S. A. G. Wensveen, J. P. Djajadiningrat, and C. J. Overbeeke. 2004. Interaction frogger: a design framework to couple action and function through feedback and feedforward. In *Proceedings of the 2004 conference on Designing interactive systems processes, practices, methods, and techniques - DIS '04*. ACM Press, Cambridge, MA, USA, 177. <https://doi.org/10.1145/1013115.1013140>
  - [35] Qian Yang, Aaron Steinfeld, Carolyn Rosé, and John Zimmerman. 2020. Re-examining Whether, Why, and How Human-AI Interaction Is Uniquely Difficult to Design. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. ACM, Honolulu HI USA, 1–13. <https://doi.org/10.1145/3313831.3376301>
  - [36] Rayoung Yang and Mark W. Newman. 2013. Learning from a learning thermostat: lessons for intelligent systems for the home. In *Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing*. ACM, Zurich Switzerland, 93–102. <https://doi.org/10.1145/2493432.2493489>
  - [37] Rayoung Yang, Mark W. Newman, and Jodi Forlizzi. 2014. Making sustainability sustainable: challenges in the design of eco-interaction technologies. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Toronto Ontario Canada, 823–832. <https://doi.org/10.1145/2556288.2557380>
  - [38] Yigzaw Goshu Yohanis. 2012. Domestic energy use and householders' energy behaviour. *Energy Policy* 41 (Feb. 2012), 654–665. <https://doi.org/10.1016/j.enpol.2011.11.028>