



HAL
open science

The Weight of Our Decisions: Encoding Carbon Impact with Physical Load

Edwige Chauvergne, Aymeric Ferron, Pierre Dragicevic

► **To cite this version:**

Edwige Chauvergne, Aymeric Ferron, Pierre Dragicevic. The Weight of Our Decisions: Encoding Carbon Impact with Physical Load. IHM 2024 - 35e Conférence Internationale Francophone sur l'Interaction Humain-Machine, Mar 2024, Paris, France. hal-04486642

HAL Id: hal-04486642

<https://hal.science/hal-04486642v1>

Submitted on 2 Mar 2024

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.

The Weight of Our Decisions: Encoding Carbon Impact with Physical Load

Le Poids de nos Décisions : Encoder notre Impact Carbone avec des Charges Physiques

EDWIGE CHAUVERGNE, Inria, Université de Bordeaux, CNRS, France

AYMERIC FERRON, Inria, Université de Bordeaux, CNRS, France

PIERRE DRAGICEVIC, Inria, Université de Bordeaux, CNRS, France

Abstract. We are rarely fully aware of the negative consequences of our decisions. This paper explores the idea of user interfaces that make negative consequences more salient by representing them as physical weights that users carry with them. We focus on conveying carbon footprint, and report on lessons learned from two self-experiments using low-tech prototypes.

Résumé. Nous sommes rarement pleinement conscients des conséquences négatives de nos décisions. Cet article explore l'idée d'interfaces utilisateur qui rendent les conséquences négatives plus saillantes en les représentant comme des poids que les utilisateurs portent sur eux. Nous nous concentrons sur la représentation de l'empreinte carbone, et nous rapportons les leçons tirées de deux expériences personnelles utilisant des prototypes de faible technicité.

CCS Concepts: • **Human-centered computing** → **HCI theory, concepts and models**; *Pointing*; Visualization techniques.

Additional Key Words and Phrases: Physicalization, weight, carbon emission, SHCI

Mots Clés et Phrases Supplémentaires: Physicalisation, poids, émission carbone, IHM Soutenable

Reference:

Edwige Chauvergne, Aymeric Ferron, and Pierre Dragicevic. 2024. The Weight of Our Decisions: Encoding Carbon Impact with Physical Load. *IHM '24 : 35^e conférence Francophone sur l'Interaction Humain-Machine, March 25–29, 2024, Paris, France*

1 INTRODUCTION

We often make decisions that benefit us in the short term, but negatively impact our health, the environment, or other living beings. In order to make better and more fair decisions, we need to better understand their negative impact and be more aware of them. Some research in human-computer interaction investigates how to use novel user interfaces to that effect. Part of it focuses on promoting pro-environmental behavior. For instance, Assor et al. [4] explored how to convey the environmental impact of our actions in a visceral way, by rendering our waste in our direct environment using augmented reality. Physical data representations have also been explored, such as the participatory data physicalization by Sauvé et al. [27], which encodes the carbon footprint of past meals through wooden tokens of different sizes.

In this paper, we extend prior research on physical data representations by exploring how to encode the negative consequences of our decisions as physical burdens we carry in our daily activities. We focus on carbon footprint, as it is expressed as a mass and therefore naturally translates to a physical weight. We report two self-experiments based on low-technology prototypes. Based on these self-experiments, we discuss benefits and opportunities of using physical load to encode the negative impact of our decisions.

IHM '24, March 25–29, 2024, Paris, France

2024. ACM ISBN XXX-X-XXXX-XXXX-X/XX/XX...\$15.00

<https://doi.org/10.1145/XXXXXXXXXXXXXXX>

2 RELATED WORK

2.1 Eco-Feedback

Our work relates to *eco-feedback* technologies, which “provide feedback on individual or group behaviours with a goal of reducing environmental impact” [10]. Various user interfaces have been developed for reducing energy use [11, 12, 25, 26], transport-related emissions [9, 21], and waste [3, 4, 16], with feedback ranging from numerical to concrete, visceral representations [4, 18]. Although eco-feedback seeks to promote positive behavior, actual behavior change is very difficult, including because people may not understand what behavior to adopt [7], and may have a limited range of options [5, 28]. Regardless, some people wish to better understand and be more often reminded of the impact of their decisions on the environment, which is invisible and easy to forget about. We explore to what extent using physical load to encode personal environmental impact may help achieve this goal.

2.2 Data physicalization

Data physicalizations are “physical artifacts whose geometry or material properties encode data” [15]. Researchers in this area have suggested that the weight of physical objects can be used to encode data [13, 15], but this idea has been very little explored. One exception is the recent design by Lindrup et al. [20], which encodes the carbon footprint of food through the weight of physical tokens which users can manipulate. We similarly explore the idea of encoding food-related carbon footprint with weight, but the weights are carried by users over extended periods of time and in a way that demands effort. All such designs encode static data ; hardware systems have been proposed for varying weight dynamically [24], but implementing dynamic weights is challenging in general.

2.3 Exertion Interfaces

Also related to our work is the area of *exertion interfaces*, i.e. user interfaces that require physical effort [23]. A few VR studies have explored turning environmental impact into effortful actions: people were asked to refill a water bottle multiple times to accumulate the equivalent of a toilet flush or a 1-min shower [14], to cut a tree to better understand deforestation caused by paper production [1], or to stack sand bags in front of their window to anticipate an upcoming flood [22]. All such actions involve physical movements and therefore real effort. Here, we focus on carrying physical loads, and we take an ambient feedback approach where the effortful activity is extended over time and integrated into daily activities, rather than being part of a one-shot experience.

3 SELF-EXPERIMENTATION 1: MEAT IMPACT

One of the co-authors (which we will refer to as the subject) conducted an informal self-experimentation over the course of two weeks in order to test the idea of carrying the physical weight of one’s emissions. The goal was also to help us reflect on the concept, identify issues, limitations and opportunities, and generate new ideas.

3.1 Method

The method was progressively developed over the course of the self-experimentation. On day 1, the subject created a spreadsheet to keep a log of all their meat consumption, including the type and weight of each meat consumed, and an estimation of its carbon footprint using external sources such as the Open Food Facts database. The focus on meat was for simplicity, and because meat has the largest carbon footprint across all food types. On day 4, the subject decided to carry each unit of weight for 30 minutes. For example, eating a burger with an estimated CO₂ footprint of 3 kg requires subsequently carrying 3 kg for 30 minutes. This arbitrary duration was chosen based on how long the first weight was carried on day 1. The subject also decided to rely on a debt scheme, where each new meat-related footprint adds to a total debt expressed in kilogram-minute, which can be reduced anytime by carrying any amount of weight for any amount of time. This approach was chosen to accommodate daily life constraints, as it does not require to carry weights every day.



Fig. 1. The low-tech prototypes we used in our self-experimentations. (a–b): 7 kg worth of sand bags carried in a backpack on day 5, corresponding to the estimated carbon emissions of various meats consumed over 4 days; (c–d): carbon impact encoded in wrist and ankle weights, summing up to 6 kg carried during a walk in the woods. (e): 2.7 kg worth of bags filled with rocks and attached to a jacket to be carried, representing the weight of a breakfast, lunch, and dinner for a single day.

3.2 Weights Carried

The subject carried different amounts of weight in different ways. A detailed log is available at <https://osf.io/mbwyd>. We provide a brief summary here. On day 1, the subject filled a freezer bag with about 400 g of sand, corresponding to the emissions of a fried rice dish containing 30 g of bacon and 30 g of shrimps. They then carried the bag in their vest pocket for 30 minutes while cleaning the table and the kitchen. On day 5, the subject had accumulated a debt of about 7 kg, which they carried as sand bags in their backpack for about 1 hour on their way to work and back, on top of their existing 5-kg backpack load (Figure 1-a,b). On day 6, the subject carried a 2-kg debt from the day before as wrist weights designed for workout, during a 30-minute work meeting (Figure 1-c). On day 11, the subject paid back a 6-kg debt by carrying wrist weights and ankle weights (Figure 1-d) for 30 minutes in a store and at home. Finally, on day 14, the subject paid back another 6-kg debt by carrying the same weights for another 30 minutes during a walk in the woods. The subject then got sick and stopped the self-experimentation.

3.3 Thoughts and Observations

Here are some observations and insights that arose during the self-experimentation. Here we report them in bulk and will organize them more systematically in the next section. More details can be found in the OSF project.

3.3.1 Awareness.

- This exercise made it very clear that the weight of a meat’s carbon emissions is significant, and always greater than the weight of the meat itself (from 5 to 30 times heavier).
- A small number of meals had a very high impact. However, the impact of those individual meals was not very salient, because the subject was typically wearing weight debts accumulated over many meals.
- The self-logging activities (e.g., estimating meat weight, searching for info about carbon impact, and maintaining a spreadsheet) did a lot of the work in increasing awareness and understanding. With the use of conditional formatting in the spreadsheet, the impact of individual meals was also very visible and salient.

3.3.2 Noticeability and difficulty.

- The weight carried in a vest pocket was more noticeable and harder to forget than the heavier weights carried in a backpack, because it produced a more unusual feeling.

- Backpack weights were much more salient when putting on and taking off the backpack, and going upstairs.
- During the work meeting, wrist weights required no effort when arms were resting on the table, but could be felt a lot when typing on the keyboard. Ankle weights felt very heavy when climbing stairs.
- Like the pocket weight, the body sensations provided by wrist/ankle weights were more unusual than a backpack, and therefore harder to ignore and to forget about.

3.3.3 *Valence.*

- Carrying weights was initially a positive experience because it was part of a fun experiment, and could be conceptualized as a healthy exercise. It however became unpleasant when the subject started to get sick, and got worse when a walk in the woods turned into a walk in a muddy and swampy area under heavy rain.

3.3.4 *Other.*

- In the woods, the subject had to go around a stream because the ankle weights did not allow safe crossing. This revealed that weights can also restrict someone's freedom of movement and set of choices.
- The subject felt self-conscious when wearing wrist and ankle weights, so they avoided doing so in public: weights were removed after the private meeting, and hid underneath clothes during the walk in the woods.
- Accumulating a weight debt felt uncomfortable and catching up felt liberating, just like e-mails.

4 SELF-EXPERIMENTATION 2: WEIGHT JACKET

Over the course of 11 days, another co-author kept track of the carbon impact of their food – all food items included – and car rides (details also in the OSF project). They also decided to prototype a weight jacket.

4.1 Prototype

The weight jacket (Figure 1-e) was made of six bags filled with gravels and attached to a jacket using safety pins. The six bags weighed 2.7 kg in total, representing the carbon equivalent weight of a breakfast, lunch, and dinner for a typical day, including one meat-based meal. However, the jacket was not used to carry the logged weights.

4.2 Thoughts and Observations

- The jacket did not constrain the subject's movements, allowing them to go through their daily activities.
- All co-authors tried the jacket and found the weights well-balanced, making them easy to carry.
- The subject soon realized that carrying the weight of car rides using the jacket would not be feasible, as the car's impact was 14 kg per day on average (min: 0 kg, max: 55 kg). After 11 days, the accumulated impact of food was 22 kg, vs. 156 kg for the car.
- Generally, the weight jacket seems more fitting for limited weights. It appears difficult to craft a very heavy weight jacket without it becoming bulky or awkward to wear.

5 DISCUSSION

Based on our literature search, our experimentation and our reflections, we propose a conceptual framework that can help think about the dimensions that need to be considered when designing a system for carrying the weight of personal carbon dioxide emissions. Then, we discuss potential difficulties and key limitations of the idea.

5.1 Conceptual Framework

5.1.1 *Duration.* How long should we carry the weight of a single decision? If we had beef at lunch, should we carry 4.6 kg for 30 minutes, an hour, or until the next meal? The decision could be arbitrary (as we did in our self-experimentation), but there are also principled ways of deriving a duration. As an example, the duration could be based on the time necessary for the Earth to absorb the same amount of CO₂. It is assumed that the

Earth's carbon sinks can absorb roughly 18.2 Gt of CO₂ per year [8] (which is about half of what was emitted in 2021). If we divide this carbon budget equally among all 8 billion people, everyone gets a personal budget of about 2.3 tons per year, that is, 6.3 kilograms per day. Therefore, a steak emitting roughly 4 kg of CO₂ would require to carry its carbon impact during 15 hours. However, this calculation is just to illustrate a principled way of deciding how long to carry a weight – its practical suitability and relevance are open to debate.

5.1.2 Time granularity. Users may carry the weight of decision after decision, or carry the aggregated weight of multiple decisions, as in our self-experiment. No aggregation might make it easier to understand the consequence of individual decisions. At the same time, aggregating multiple decisions (e.g., a week worth of meat) can lead to an experience that is much more salient. Conversely, the weight of a single decision can be carried all at once, or split and carried on several occasions over time. Some decisions are too heavy to be carried at once, e.g., a 250-km car trip emits 55 kg. Some people may be able to carry this weight, but most likely prefer to carry, e.g., ten times 5.5 kg instead. However, in doing so, they might not feel the weight as much. How time granularity affects the subjective experience of effort is an important question that needs to be addressed by psychology research.

5.1.3 Delay. The weight of a decision can be carried as soon as the decision is made or later in time. Delay relates to time granularity, because aggregating multiple decisions implies delaying carrying the weight of the first decisions. In general, immediate carrying likely facilitates the mental association between the decision and its negative impact. However, achieving zero delay seems technically challenging. In principle, we could imagine intelligent actuated vests that get instantly heavier as we make decisions, but as we already discussed in subsection 2.2, supporting dynamically-varying weights is challenging. In addition, for such a vest to be safe, it would have not to change during activities such as driving or biking. We could instead imagine a vest that updates its weight when we dock it to a liquid pump, which is more realistic but does not achieve zero delay. However, despite the possibilities offered by all such user interface technologies, there remain clear benefits to using low-tech solutions such as ours, including ease of implementation and lower environmental impact [19]. Note that we could also carry the weight of meals *before* eating them, e.g., to get a preview before we decide.

5.1.4 Weight granularity. Weights can be more or less precise depending on the equipment used. Sand or water can be adjusted precisely, but they require containers and DIY skills to be attached to body parts. In contrast, weights designed for workouts are convenient and can be used immediately, but they only permit adjustments in discrete steps. In our case, we only had access to 1-kg and 2-kg weights for wrists and ankles, requiring us to round the numbers. However, since carbon emission estimates are typically imprecise, this might not be an issue.

5.1.5 Coverage. People may decide to carry the weight of all or most of their decisions (high coverage), or only focus on a specific type of decision (low coverage). High coverage is difficult to achieve in practice, unless advanced sensing and inference technology is developed in the future – for example, we could imagine a wearable system that continuously tracks the user's physical and digital activities, and uses machine learning to estimate the carbon impact of their decisions in real time. But in practice, today, low coverage is the only realistic option. Low coverage can have advantages, however, as it can help users focus on specific objectives: for example, a user could decide to focus on improving their travel habits or food habits, and to set themselves a daily budget.

5.1.6 Carrying method. As our self-experiments illustrated, there are many ways to carry weights. Some distribute the load over the body (the weight jacket) or put it on places where it is natural to carry weights (a backpack). Unless the load is very heavy, these methods allow carrying weights during daily activities without any major discomfort and over potentially long periods of time. However, users may end up completely forgetting the weights. Some methods (e.g., ankle and wrist weights) put weights on potentially unusual places and might have more potential to maintain sustained awareness, although habituation may form. Other approaches may involve purposeful action from users, such as weightlifting equipment whose difficulty depends on past carbon emissions.

5.2 Difficulties and Limitations

5.2.1 Unclear if it leads to behavior change. The ultimate measure of success for any eco-feedback system is behavior change. We have only started to explore a concept, and have not collected any evidence that carrying the weights of our decisions can effectively lead to positive, lasting behavior change. There are plausible mechanisms by which it could be the case. Ambient data physicalizations such as these can make the negative impact of users' decisions more salient, make the quantities more visceral, and therefore improve their awareness and understanding. This could in turn lead to behavior change, at least some of the time. For example, a user who needs to choose between beef and a plant-based steak may associate beef with a memorable past experience of having to carry a heavy load, and thus choose the second option. But this needs to be confirmed by studies. There are also reasons why such systems could sometimes lead to *negative* behavior change, as discussed next.

5.2.2 Undesirable consequences. Many aspects of the system are outside the designer's control and can lead to unforeseen consequences. For one, the valence of a weight-carrying activity is hard to predict – it highly depends on people and their situation, and it can range from very painful to highly pleasurable. The potential for pain or even harm raises serious ethical concerns. Conversely, it seems wrong that carrying personal carbon emissions could be experienced as a fun or healthy exercise. But the main point of the system is to promote self-awareness, not to provide a way of humiliating or shaming, or a means of self-punishment or penance. If the activity is experienced as neutral or fun but causes users to think more often about carbon impact, this is positive, as long as it does not encourage bad behavior. Another risk is that the system triggers a moral licensing effect [17]. After having carried the weight of their decisions, some users may feel like they atoned for their bad decisions, and therefore feel free of guilt. This may cause them to maintain their behavior or adopt even worse behaviors.

5.2.3 Small and specific user base. Using such a system can only be a personal choice. Therefore, it cannot be used to educate people for whom carbon emissions are not a major concern. Thus it may seem that this type of system is “preaching to the choir”, by targeting people who are already sensitive to environmental issues. However, we know that people's decisions are rarely aligned with their attitudes [2]. Therefore, many people may welcome a system that acts as a constant reminder of their commitments, and motivates them to act in a way that aligns with their ideals. A valid criticism is that such a user base could be a tiny proportion of the population.

5.2.4 Not very informative. The information provided to users is minimal: users can make inferences, e.g., they can learn the food items with the most impact after having tried different dishes and carried different weights. However, the insights that can be gained from an interactive visualization system are far richer [6]: such a system could give a much better overview of the different decisions and their emissions, show trends over time, and give detailed information about the causes of the emissions. We envision weight-carrying systems as a complement, not as a replacement. Similarly, it is not enough for users to know what they did bad – they need to be explained how to do better. This could be addressed by decision-support systems, possibly wearable ones, that help users make decisions aligned with their personal goals. Nonetheless, weight-carrying systems have the opportunity to fill a unique niche by adding a tangible, vivid, and pervasive dimension that can help promote behavior change.

6 CONCLUSION

We began to explore the idea of user interfaces that convey the negative consequences of our decisions as physical loads. We identified both promising opportunities and serious challenges. We focused on carbon emissions as a case study. Our approach and most of our discussions could be generalized to other types of negative consequences, although if they have units other than mass or volume, the mapping might not be as natural.

ACKNOWLEDGEMENTS

This work arose from a seminar workshop. We thank the organizers, and Anastasia Bezerianos and Mickael Sereno for their ideas. This work was supported by grants ANR-19-CE33-0012 and ANR-22-CE33-0003.

REFERENCES

- [1] Sun Joo Grace Ahn, Jeremy N Bailenson, and Dooyeon Park. 2014. Short-and long-term effects of embodied experiences in immersive virtual environments on environmental locus of control and behavior. *Computers in Human Behavior* 39 (2014), 235–245.
- [2] Ian Alcock, Mathew P White, Tim Taylor, Deborah F Coldwell, Matthew O Gribble, Karl L Evans, Adam Corner, Sotiris Vardoulakis, and Lora E Fleming. 2017. 'Green' on the ground but not in the air: Pro-environmental attitudes are related to household behaviours but not discretionary air travel. *Global Environmental Change* 42 (2017), 136–147.
- [3] Ferran Altarriba, Stefano Eugenio Lanzani, Ana Torralba, and Mathias Funk. 2017. The grumpy bin: reducing food waste through playful social interactions. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems*. 90–94.
- [4] Ambre Assor, Arnaud Prouzeau, Pierre Dragicevic, and Martin Hachet. 2024. Augmented-Reality Waste Accumulation Visualizations. *ACM J. Comput. Sustain. Soc.* (jan 2024). <https://doi.org/10.1145/3636970> Just Accepted.
- [5] Hronn Brynjarsdottir, Maria Håkansson, James Pierce, Eric Baumer, Carl DiSalvo, and Phoebe Sengers. 2012. Sustainably unpersuaded: how persuasion narrows our vision of sustainability. In *Proceedings of the sigchi conference on human factors in computing systems*. 947–956.
- [6] Stuart K Card, Jock Mackinlay, and Ben Shneiderman. 1999. *Readings in information visualization: using vision to think*. Morgan Kaufmann.
- [7] Myriam Fréjus and Dominique Martini. 2015. Taking into account user appropriation and development to design energy consumption feedback. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*. 2193–2198.
- [8] Pierre Friedlingstein, Michael O'sullivan, Matthew W Jones, Robbie M Andrew, Luke Gregor, Judith Hauck, Corinne Le Quéré, Ingrid T Luijkx, Are Olsen, Glen P Peters, et al. 2022. Global carbon budget 2022. *Earth System Science Data Discussions* 2022 (2022), 1–159.
- [9] Jon Froehlich, Tawanna Dillahunt, Predrag Klasnja, Jennifer Mankoff, Sunny Consolvo, Beverly Harrison, and James A Landay. 2009. UbiGreen: investigating a mobile tool for tracking and supporting green transportation habits. In *Proceedings of the sigchi conference on human factors in computing systems*. 1043–1052.
- [10] Jon Froehlich, Leah Findlater, and James Landay. 2010. The design of eco-feedback technology. In *Proceedings of the SIGCHI conference on human factors in computing systems*. 1999–2008.
- [11] Anton Gustafsson, Magnus Bång, and Mattias Svahn. 2009. Power explorer: a casual game style for encouraging long term behavior change among teenagers. In *Proceedings of the international conference on advances in computer entertainment technology*. 182–189.
- [12] Tiffany Grace Holmes. 2007. Eco-visualization: combining art and technology to reduce energy consumption. In *Proceedings of the 6th ACM SIGCHI conference on Creativity & cognition*. 153–162.
- [13] Eva Hornecker. 2011. The role of physicality in tangible and embodied interactions. *interactions* 18, 2 (2011), 19–23.
- [14] Wei-Che Hsu, Ching-Mei Tseng, and Shih-Chung Kang. 2018. Using exaggerated feedback in a virtual reality environment to enhance behavior intention of water-conservation. *Journal of Educational Technology & Society* 21, 4 (2018), 187–203.
- [15] Yvonne Jansen, Pierre Dragicevic, Petra Isenberg, Jason Alexander, Abhijit Karnik, Johan Kildal, Sriram Subramanian, and Kasper Hornbæk. 2015. Opportunities and challenges for data physicalization. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. 3227–3236.
- [16] Debbie Jung. 2023. CoCo: Compost Companion: Design and Evaluation of a Wearable Pet That Supports Composting Habits Towards an Interaction Design for Empathy. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*. 1–7.
- [17] Uzma Khan and Ravi Dhar. 2006. Licensing effect in consumer choice. *Journal of marketing research* 43, 2 (2006), 259–266.
- [18] Benjamin Lee, Dave Brown, Bongshin Lee, Christophe Hurter, Steven Drucker, and Tim Dwyer. 2020. Data visceralization: Enabling deeper understanding of data using virtual reality. *IEEE Transactions on Visualization and Computer Graphics* 27, 2 (2020), 1095–1105.
- [19] Catherine Letondal, Aurélien Tabard, Laetitia Bornes, Augusto Esteves, Martin Hachet, Valérie Maquil, and Anne Roudaut. 2023. Tangible Interaction and Industrial Degrowth. In *HCI for Climate Change. Imagining Sustainable Futures-Workshop at CHI 2023*.
- [20] Martin Valdemar Anker Lindrup, Arjun Rajendran Menon, and Aksel Biørn-Hansen. 2023. Carbon Scales: Collective sense-making of carbon emissions from food production through physical data representation. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference*. 1515–1530.
- [21] Vikram Mohanty, Alexandre LS Filipowicz, Nayeli Suseth Bravo, Scott Carter, and David A Shamma. 2023. Save A Tree or 6 kg of CO2? Understanding Effective Carbon Footprint Interventions for Eco-Friendly Vehicular Choices. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. 1–24.
- [22] Jantsje M Mol, WJ Wouter Botzen, and Julia E Blasch. 2022. After the virtual flood: Risk perceptions and flood preparedness after virtual reality risk communication. *Judgment and Decision Making* 17, 1 (2022), 189–214.
- [23] Florian 'Floyd' Mueller, Yan Wang, Zhuying Li, Tuomas Kari, Peter Arnold, Yash Dhanpal Mehta, Jonathan Marquez, and Rohit Ashok Khot. 2020. Towards experiencing eating as play. In *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction*. 239–253.
- [24] Ryuma Niiyama, Lining Yao, and Hiroshi Ishii. 2014. Weight and volume changing device with liquid metal transfer. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction*. 49–52.

- [25] Dane Petersen, Jay Steele, and Joe Wilkerson. 2009. WattBot: a residential electricity monitoring and feedback system. In *CHI'09 extended abstracts on human factors in computing systems*. 2847–2852.
- [26] Petromil Petkov, Felix Köbler, Marcus Foth, and Helmut Krcmar. 2011. Motivating domestic energy conservation through comparative, community-based feedback in mobile and social media. In *Proceedings of the 5th International Conference on Communities and Technologies*. 21–30.
- [27] Kim Sauvé, Pierre Dragicevic, and Yvonne Jansen. 2023. Edo: A Participatory Data Physicalization on the Climate Impact of Dietary Choices. In *Proceedings of the Seventeenth International Conference on Tangible, Embedded, and Embodied Interaction*. 1–13.
- [28] Yolande AA Strengers. 2011. Designing eco-feedback systems for everyday life. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 2135–2144.