Challenges and Design Considerations for Home-based Visualisations to Encourage More Sustainable Practices

Dushani Perera
Cardiff University, UK
PereraUD@cardiff.ac.uk

Nervo Verdezoto Dias
Cardiff University, UK
VerdezotoDiasN@cardiff.ac.uk

Julie Gwilliam
Cardiff University, UK
GwilliamJA@cardiff.ac.uk

Parisa Eslambolchilar
Cardiff University, UK
EslambolchilarP@cardiff.ac.uk

This paper investigates household preferences for visualising consumption data and explores the potential of physical visualisations to enhance user engagement and encourage sustainable practices at home. We conducted thirteen household interviews using a combination of images and objects to understand participants' expectations and preferences for visualising consumption data. We identified images that generate empathy, images that trigger revulsion around the home, objects that aid bonding with household members, and places in the home for collaboration and engagement. The study identified particular physical objects and locations within the house that contribute to nurturing family connections to collectively work towards reducing consumption. Participants preferred a physical visualisation of their consumption data in their houses compared to screen-based visualisations. We open space to consider designing physical visualisations for home collaboration and better user engagement to enhance households' awareness of curtailing consumption.

Data Physicalisation, Climate Change Communication, Sustainable HCI

1. INTRODUCTION

Climate change is driven by increasing carbon emissions and household consumption accounts for around two-thirds of global greenhouse gas emissions (UNEP 2020). Household consumption means the amount of resources used to perform daily activities such as heating, food consumption and other needs (Druckman and Jackson 2010). To address climate issues, it is crucial to raise awareness and implement strategies to change consumption practices. For example, it is argued that visualisations could influence human actions by making complex information understandable and revealing the typically invisible aspects of consumption (Fredericks et al. 2019).

Over the past years, visualisation technology on eco-feedback on resource consumption has provided feedback on individual behaviours with the goal of reducing climate impact (Barreto et al. 2022). These technologies can take many forms including smart meters, web/mobile applications, games, virtual environments, tangible user interfaces, and data physicalisations (Stegers et al. 2022; Sauvé et al. 2020; Dragicevic et al. 2019). Consumption information provided to households via various methods results in an increase in awareness, however, may not necessarily lead to adopting resource conservation behaviours (Abrahamse et al. 2018; Perera et al. 2023). Screen-based visualisations have low engagement as they only convey the problem (amount of resources utilised) rather than making a connection between the problem and a solution (Goodhew et al. 2014).

To explore encouraging sustainable practices at home, we conducted an exploratory study with 13 households to investigate consumption practices and experiences, and contextual factors interwoven with these domestic consumption activities. Our research contributes to the growing body of work on understanding the design of technology to enhance user experience going beyond the ideals of solely focusing on the technicality of visualisation

(Fernando et al. 2009; Baillie and Benyon 2008; Dillahunt et al. 2017; Bartram 2015).

2. RELATED WORK

To situate our work, we consider relevant research in HCI related to the visualisation of home consumption. We describe eco-feedback visualisations in the literature (screen-based visualisations, ambient visualisations, data physicalisations) and their limitations to highlight the need for designing technology to support household consumption curtailment.

2.1. Screen-based Visualisations

While screen-based visualisations (Fernando et al. 2009) offer advantages in accessing detailed or historical data, it can require constant attention which disrupts the focus of a person (Jáuregui and Couture 2019). Screens and mobile applications require intentional effort and focused attention to comprehend visualised data (Bartram 2015). For instance, smart meters have been implemented to empower residential customers to become aware and have better control over their energy usage (De Dominicis et al. 2019). Dillahunt et al. (2017) communicated the impact of global warming on polar bear survival chances. While smart meters offer real-time feedback on electricity use (De Dominicis et al. 2019), their impact on reducing consumption is limited, typically by 3 per cent or less (Guardian 2016). Engaging with screen-based visualisations can be challenging for people, due to the lack of connection between the problem (resource utilisation) and potential solutions (Goodhew et al. 2014). Although meter readings are the typical strategy of measuring household energy use, people find it difficult to engage with them (Steg 2008). Although well-designed displays are helpful for data analysis, they do not often assist in at-a-glance understanding that is necessary to support in-the-moment decision-making (Bartram 2015).

2.2. Ambient Visualisations

Ambient Canvas (Bartram et al. 2011) is an ambient display on a kitchen backsplash that serves as a dynamic art piece rendering an energy consumption using layers of light waves. Iribagiza et al. (2020) developed an in-house display to depict air quality feedback to promote improved adoption of liquefied petroleum gas cookstoves by colouring a child's lungs with black dots. They reported that the households preferred the use of a metaphor of a baby's lungs in the in-house display and noted that it reminded them of their own children's health. However, an issue that arises with ambient visualisations is functional aesthetics of how the placement of the display forms a part of how people use the space (Bartram et al. 2010). For example, when light streamed into the home or the occupants were working on the counter in the early evening, the Ambient Canvas was not bright enough (Bartram et al. 2010) to be clearly seen. Further, it is argued that these are isolated approaches that have not been incorporated into a holistic household ecosystem by understanding the home context and its diverse practices (Bartram et al. 2010).

2.3. Data Physicalisations

A physical artefact whose geometry or material qualities encode data is referred to as a 'data physicalisation' or 'physical visualisation' (Dragicevic et al. 2019). It offers varying levels of data abstraction by engaging different human senses (Eslambolchilar et al. 2023). Data physicalisations aim to aesthetically manifest data in a physical form which has been utilised in climate-change related HCI research (Sauvé et al. 2020; Backlund et al. 2006; Katzeff et al. 2017). Data physicalisations, with their artistic and functional qualities, are gaining popularity across domains, promoting engagement and better user experience (Rasmussen et al. 2012). Unlike, traditional visualisation techniques on 2D digital displays, physical forms of data visualisation seamlessly integrate into daily routines, raising awareness of consumption data (Eslambolchilar et al. 2023). They provide an abstract understanding of data in the periphery of attention (Eslambolchilar et al. 2023) by blending into the background and not disrupting the user's actions making them valuable tools for busy lifestyles (Stegers et al. 2022).

3. STUDY DESIGN

To gain insights into households' expectations and preferences for visualising consumption data, 13 semi-structured household interviews were conducted in this study. The semi-structured nature of the interview allowed for flexibility and depth, allowing participants to share their unique opinions and personal stories. This enabled us to unpack and map the relationship between households' experiences and existing strategies to curtail consumption by focusing on individual contexts, collective household factors, sociocultural practices and norms. The average duration of the interviews was one and a half hours. We prepared four activities (normal routine activities in the home, existing strategies used to curtail consumption, views on visualisations done in the literature to help households reduce consumption, and thoughts about the proposed low-fidelity prototypes (Lim et al. 2008) and any new ideas). This study was conducted between July 2022 and October 2022. The recruitment took place at the household level,

then all consenting households were asked to sign an informed consent. A £50 voucher was provided per household as a financial incentive. Ethical approval was granted by the ethics committee of the School of Computer Science and Informatics, Cardiff University (approval no: COMSC/Ethics/2022/056).

3.1. Participants

Interviews were conducted in and around Wales, UK. We recruited 13 households (one to six members per household) with ages ranging from 18 years to 54 years (refer Table 1). We decided on the sample size based on saturation as the frequency of generating new codes reduced in each successive interview and significantly reduced after the seventh interview. We advertised on the Cardiff University social media group and utilised emailing lists for participant recruitment. We decided on the inclusion criteria to have a wider representation of households across varying socio-economic contexts, as this was an exploratory study (Allmark 2004). Therefore, we recruited participants from a range of diverse income categories as set by the Office of National Statistics, UK (ONS 2019) (Table 1). We also recruited participants from different household types (single-user, couple/partner houses, and family homes). Furthermore, the participants were contacted by email to confirm their willingness to participate and were asked, at this time, to consider what might be their objects in the household that symbolised sustainability or climate change. "Symbolises sustainability or climate change" was framed as useful, long-lasting or environment friendly. This provided them with the opportunity to think about their response ahead of the interview.

3.2. Data Collection

First, we displayed images from the literature (see below for explanations) (Fernando et al. 2009; Bartram et al. 2011; Sauvé et al. 2020; Iribagiza et al. 2020; Dillahunt et al. 2017) of different types of consumption-related visualisations to understand participants' views on each of them. Next, we displayed two low-fidelity paper prototypes (Lim et al. 2008) ('moving flowers' and 'Betta fish' in Figure 1) and two images as visualisations ('lighting chandelier' and "wall-climbing men' in Figure 1) leveraging the literature (Hong et al. 2015; Yoon et al. 2013; Degraen et al. 2022; Antifakos and Schiele 2003; Backlund et al. 2006) to facilitate the understanding and communication during the interview (see below for explanations).

3.2.1. Description of the images from the literature

We selected images from the literature to address design considerations utilised by prior work to visualise household consumption (Fernando et al. 2009; Dillahunt et al. 2017; Bartram et al. 2011; Sauvé et al. 2020; Iribagiza et al. 2020). We intended to display these images for participants to explore their opinions about six design considerations based on the literature: 1) use of different coloured lights (Sauvé et al. 2020; Bartram et al. 2011), 2) use of climate-related empathetic visuals (visuals attached to nature or climate) (Fernando et al. 2009; Dillahunt et al. 2017), 3) using images of household objects (visuals attached to a household item) (Bartram et al. 2011), 4) using images of regular objects (visuals with no attachment to nature or climate) (Sauvé et al. 2020), and 5) use of visual that increase shock value (Iribagiza et al. 2020).

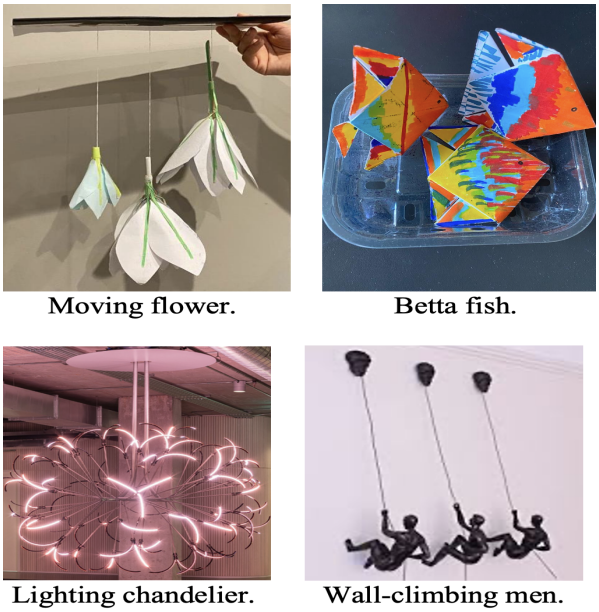

Figure 1: *The low-fidelity paper prototypes ('moving flower' and 'Betta fish') and images ('lighting chandelier' and 'wall-climbing men') utilised in the household interview.*

3.2.2. Low-fidelity paper prototypes and images

We designed two low-fidelity paper prototypes (Lim et al. 2008) ('moving flower' and 'Betta fish' in Figure 1), and utilised two images as visualisations ('lighting chandelier' and 'wall-climbing men' in Figure 1). It is important to note that the purpose of the paper prototypes and the images was not to let the participants use them or consider them as a formal design evaluation (Lim et al. 2008), but to use them for communication, understanding, and triggering discussion and sharing of ideas. Each low-fidelity paper prototype or image addresses a design consideration identified through the literature: 1) shape-change of objects (Rasmussen et al. 2012) (the 'moving flowers low-fidelity paper prototype' of Figure 1), 2) 'lighting chandelier' of Figure 1 addresses static physicalisations (Sauvé et al. 2020) and using lights (Hong et al. 2015), 3)

Table 1: *Participant demographics information*

Household (H)	Household type. NF - Nuclear family, SH - Shared house between partners, SO - Singe Occupant	No. of members in the house	No. of participants in the discussion	Age ranges of the participants	Genders of the participants	Mean average annual household income
H1	NF	4	1	18-24	Male	31k to 36k
H2	SH	4	2	25-34	Male , female	43k to 67k
H3	SH	2	2	25-34	Male , female	43k to 67k
H4	SH	2	2	25-34	Male , female	11k to 26k
H5	NF	3	2	25-34	Male , female	11k to 26k
H6	NF	4	2	35-44	Male , female	43k to 67k
H7	NF	2	1	45-54	female	43k to 67k
H8	NF	3	2	25-34	Male , female	43k to 67k
H9	NF	2	2	45-54	Male , female	$>$ 67k
H10	SO	1	1	35-44	female	36k to 43k
H11	NF	6	1	25-34	female	43k to 67k
H12	NF	5	2	35-44	Female, Female	26k to 31k
H13	SH	2	2	25-34	Male , female	$>$ 67k

empathetic visualisations (Fernando et al. 2009) ('Betta fish low-fidelity paper prototype' of Figure 1), and 4) gamified visualisations (Willemsen et al. 2011) ('wall-climbing men' of Figure 1). Moreover, in the process of preparing these low-fidelity paper prototypes and images, we were inspired by the considerations in the literature to design for: 1) household collaboration, 2) peripheral interaction, and 3) shared location in the house (Stegers et al. 2022).

Leveraging prior work (e.g., flower-shaped actuated physical ambient avatar (Hong et al. 2015), Laughter Blossom (Yoon et al. 2013), FamilyFlower (Degraen et al. 2022), LaughingLily (Antifakos and Schiele 2003), Flower Lamp (Backlund et al. 2006), Peacetime (Katzeff et al. 2017), and blossoming flower displaying music data (Kim et al. 2015)) we designed the 'moving flowers low-fidelity paper prototype' (Figure 1) to explore the user engagement with shape-change of data physicalisations (Rasmussen et al. 2012) and use of nature-based visuals (Fernando et al. 2009). This low-fidelity paper prototype is a set of 3 flowers that bloom and hang from the ceiling. Further inspired by The Clouds (Rogers et al. 2010), we designed the flowers to move vertically in response to households' consumption. Inspired by Econundrum (Sauvé et al. 2020), 'lighting chandelier' (Figure 1) is an image that visualises a static (non-movement) installation which has LED strips that could light up in different colours to inform occupants of their consumption. 'Betta fish low-fidelity paper prototype' was inspired by Tamagotchi (Bloch and Lemish 1999), Pet-literal interface (Dillahunt et al. 2017), empathetic biological media (Fernando et al. 2009), and natural colour change occurring with Betta fish (Bettas 2018). We designed 'Betta fish low-fidelity paper prototype' to comprehend the users' opinions on colour changes with empathetic visuals where the colour change of the fish object occurs based on the household's consumption. Finally, 'wall-climbing men' was inspired by gamification (Willemsen et al. 2011) where objects representing different consumption sectors (such as energy, water, and food waste etc.) travel autonomously to reach parallel targets.

3.3. Data Analysis

The notes and interview recordings were transcribed with the aid of NVivo (release 1.7.1). Our data

analysis strategy was based on Braun and Clarke's guidelines for reflexive thematic analysis (Braun and Clarke 2021). We started by getting familiar with the qualitative data to obtain an improved understanding of the context and participants. We created codes to gather important data, considering how our perspectives may influence the choice and understanding of codes. We reviewed the codes, looking for patterns, relationships, and interconnections. We gathered similar codes to discover potential themes. We kept revisiting and refining themes and iteratively reviewing the transcripts to facilitate theme identification until no new themes emerged. In each round, the research team discussed the results. We identified that user needs and preferences around home-based visualisations that could encourage sustainable household practices was a common theme among participants. Therefore, we began to rearrange and review the data to investigate the challenges and opportunities related to this topic. After getting input from discussions with the research team, we rearranged the overarching themes and placed sub-themes under the main themes. We analysed the empirical material and we present our qualitative findings through five main themes highlighting the participants' thoughts and desires in the design of home-based visualisation that would help reduce household consumption: 1) Integrating Empathy into Design, 2) Using Goal Setting or Competition, 3) Using Shape Change (of a Flower Blooming) as a Positive Reward or Shock Value as Motivation, 4) Physicality and Interpretability, and 5) Satellite System: Involving Children in the Conversation of Reducing Consumption.

4. FINDINGS

In the following subsections, we describe the multiple experiences of households attempting to lower their consumption while reconciling discrepancies in household dynamics and diverse requirements.

4.1. Integrating Empathy into Design

Most households specifically preferred the 'moving flowers low-fidelity paper prototype' of Figure 1): *"I think the flowers are more of a visual that captures the eye"* (H2). Moreover, participants preferred visualisations based on emotive metaphors such as living organisms. Participants indicated that these would provide more *"life impact"* (H4) as humans can relate to living beings and that "*a certain level of emotiveness is needed [in the visualisation], otherwise it is not going to achieve anything*" (H2). For instance, H4 owned a smart meter that displays consumption numerically while a statistical chart displayed consumption rising as soon as an appliance is switched on. However, H4 mentioned how the smart meter *"does not have an emotional value"*. Looking at 'moving flowers low-fidelity paper prototype' of Figure 1), H2 further suggested having a *"fish swimming across your ceiling or butterfly and birds and the flowers, you can have the coral reefs or mangroves or seagrass with fish"*. Similarly, H4 suggested being able to plant some flowers for the bees and butterflies to have a *"more active positive impact on the environment"*. H11 mentioned that the display of child's lungs in (Iribagiza et al. 2020) was "quite stark" and would not be suitable for their household.

4.2. Using Goal Setting or Competition

H2 noted that understanding their performance in consumption reduction in comparison to the UK average household, tracking their past consumption, and setting goals and controls within the house could aid in achieving their targets: *"we could look at the UK average and you can set a budget against it and then we are rewarded if, at the end of the day, we are within budget"*. Another strategy found during the interviews was that competition may be healthy in certain situations. H3 expressed this through an example: *"we both [the partners living in the house] have Fitbits and we participate in a weekly step challenge, (...) I might beat him in the step challenge"*. However, H9 and H11's opinion was that competition may be an effective strategy for children but not for adults as they thought that would lead to *"naming and shaming"* among adults.

4.3. Using Shape Change (of a Flower Blooming) as a Positive Reward or Shock Value as Motivation

Referring to the 'moving flowers low-fidelity paper prototype' (Figure 1), H2 and H11 interpreted the blooming of the flower as a reward: *"you would want the feedback to be a positive reinforcement. So if you are doing well during the day, the flowers bloom"*. Positive reinforcement was found to be preferred by 11 households during the discussion where H2 explained their willingness to look at trees grow as opposed to wilt: *"if you do well during the day, then the living metaphor could be that you've planted lots of trees. So by the end of the day, you've got a lush forest, whereas if you didn't do so well, maybe you only plant one or two trees"* (H2). Additionally, H2 mentioned that the visualisation should put their minds at ease in the long-term as opposed to making them *"feel uncomfortable"* as they might not know how to reduce the consumption that is displayed and that could be *"quite worrying"*. Nonetheless, H10 mentioned that using *"shock value"* as a means to motivate to reduce consumption would *"make people numb"* referring to (Iribagiza et al. 2020).

4.4. Physicality and Interpretability

4.4.1. Mapping Ambiguity between Physicality and Consumption Data

An important aspect for households was clarity in the presentation of the visualisation. Referring to the 'moving flowers low-fidelity paper prototype' (Figure 1), H11 attempted to understand what could be denoted through the blooming of the flower: *"[at the end of the day] it has bloomed. So I have done well, but then you would think, 'how well?'"*. H7 attempted to understand how to map their consumption to the amount of melting ice referring to (Dillahunt et al. 2017): *"If I start today with the polar bear, as the day goes by, the ice shrinks. But how would I know how much I would have used?"*. Therefore, households need to be offered a frame of reference for clear comparison: *"if it is giving [data] as the kilowatt use per day, then what is a good kilowatt?"* as H7 poignantly summarised. During the discussion of the object(s) participants brought that symbolised climate change or sustainability, households presented refillable bottles, a reused wooden ornament, refillable face makeup, glass bottle, water bottle that has been used for many years. They spoke about the durability of the physicality and material, reusability, and prevention of extra consumption and expenditure while displaying their object.

4.4.2. Hybrid Functioning, Peripheral, and Best of Two Worlds

Four households expressed the need for the 'moving flowers low-fidelity paper prototype' or 'lighting chandelier' (Figure 1) to be a hybrid visualisation that seamlessly combines the functionality of a regular light with the capability to represent their consumption information visually. Further, participants conveyed that the visualisation should not take too much space and need to be independent of the space utilised for day-to-day activities. H2 related it to the 'moving flowers low-fidelity paper prototype' (Figure 1): *"I like things on the ceilings because ceilings are not really used at all (...) and they don't take up space. If it were on the kitchen work surface or your desk, it would just be in the way"*. H1 was particularly intrigued by the autonomous functioning of the 'moving flower low-fidelity paper prototype' (Figure 1): *"I quite like that. It will be nice in the house because there isn't anything else in the house that sort of moves in a very autonomous sort of way. (...) It is a 'moving reminder'"*. The majority of the participants (11 participants) preferred to have a data physicalisation in the house as a continuous visual reminder coupled with a mobile or web application that provides a detailed view as *"it gives you the best of two worlds"* (H2 and H6). H6 continued to explain their view of this: *"The physical object is for you as a reminder to achieve the goal and the app which tells you the rest of the information with the numbers"*.

4.5. Satellite System: Involving Children in the Conversation of Reducing Consumption

H9 suggested that it could be helpful to have different visualisations as a *"satellite system"* to approach children and parents in the household: *"if you could somehow have satellite systems, like a hub and spoke. So we have the LED light thing ['lighting chandelier' of Figure 1] in the hallway that we could see. And you stack those ['wall-climbing men' of Figure 1] in the kids' room"*. H8 discussed handing over the visualisation to her son for a week and asking him to take responsibility for reducing overall consumption: "*[referring to her son] Keep this in your room this week. You keep an eye on it. You tell us when are we doing a good job? When we are not doing a good job*".

5. DISCUSSION

Our findings highlight the importance of looking at households as a collaboration of many people to obtain insights regarding the practices and how this understanding could inform the design of visualisations for curtailment of consumption. Reflecting on these findings and previous HCI research in household consumption, our study expands the understanding of visualising household consumption (Willemsen et al. 2011) and attaching meanings to objects and places in the home (Baillie and Benyon 2008). Our findings highlighted three features of objects and places around a household: Comforting vs revolting images, Objects for bonding with household members, and Places in the home for collaboration and engagement.

5.1. Comforting vs Revolting Images

To successfully motivate occupants to reduce consumption, visualisations should be aesthetically pleasing and translate abstract concerns into tangible issues (Pierce et al. 2008). Participants generally preferred nature-based visuals which evoke empathy and prompt action towards climate change. This preference may stem from humans' innate empathy for living organisms (Pierce et al. 2008). In contrast to the findings of Iribagiza et al. (2020), who reported a preference for displaying child's lungs, we found that this display was "quite stark". This discrepancy may be attributed to frictional feedback (Laschke et al. 2015), which introduces friction and choice to instigate change, inspiring reflection and alternative actions. Integrating positive feedback with frictional feedback as a balanced approach may be interesting to study how people adjust their practices accordingly:

starting with frictional feedback to raise awareness and create a sense of urgency while providing positive feedback to encourage and reinforce sustainable behaviour change.

5.2. Objects for Bonding with Household Members

The 'moving flowers low-fidelity paper prototype' and 'wall-climbing men' (Figure 1) encouraged collaborative discussions among home members and made adults think of their children's engagement with those. We are left to wonder why these two designs took parents' minds to children and began explaining happily how they will act around those. On the one hand, it may be that they saw features that would engage children which made them draw inferences about what their children prefer in a data physicalisation. On the other hand, this merits further investigations to understand what causes certain objects to remind family members of others in the home and how family bonds could be utilised in technology to encourage consumption reduction.

5.3. Places in the Home for Collaboration and Engagement

During the interviews, participants discussed how the low-fidelity paper prototypes would fit into the dining room where everyone gathers. Within the family household, a data physicalisation could be positioned in a shared central space to allow all members to reflect on their environmental behaviour and it will facilitate a meeting place for discussion (Stegers et al. 2022). Notably, H9 presented the idea of having a 'satellite system' and suggested the hallway as a good place for the visualisation for adults while the bedrooms will be the best for the children. This suggests that the designer could consider shared locations to achieve the result of having a visualisation that motivates each person to reduce their consumption.

5.4. Design Implications

Technology use at home involves the aesthetics and experiences of people in a domestic environment (Baillie and Benyon 2008). It is essential to understand that no single strategy will work for everyone because individuals have different motives, choices, and circumstances (Starke et al. 2020). A combination of strategies discussed below tailored to households may be a successful approach to encourage people to engage in sustainable activities.

5.4.1. Data Physicalisation with Positive Messages and Personalised Suggestions

Our study displayed discrepancies among households regarding preferences and expectations in a visualisation. Therefore, tailoring the feedback to the specific needs and preferences of each household by considering their unique circumstances, consumption patterns, and goals could be an opportunity to create effective data physicalisation. Personalised feedback increases relevance and resonates more effectively with individuals (Houben et al. 2016). Our findings show that a visualisation targeted toward household consumption reduction should positively reinforce users towards adopting sustainable practices (Ferreira et al. 2021). For instance, Dillahunt et al. (2017) reported that the polar bear interface was effective in their study, however, we found that our participants did not prefer to look at the polar bear drowning but wished to see it surviving. Data physicalisations have the potential to evoke emotional responses and create a deeper connection between individuals and their consumption data. By incorporating design elements that elicit emotions such as empathy, concern, or satisfaction, data physicalisations could foster a sense of responsibility and motivate individuals to make positive changes in their consumption practices.

5.4.2. Goal Setting as a Strategy

Aligning with the work conducted by Barreto et al. (2022), participants in our study mentioned being able to set goals and controls over their consumption as a major preference. Although the literature states that comparative feedback, has shown success in reducing energy consumption, our findings may suggest that people prefer goal-setting than competition which some households perceived to be derogatory to one's performance (Abrahamse et al. 2018). It is difficult not to notice its resemblance to existing behavioural models such as goal-setting (Locke and Latham 1991) to what would enable such goals to define individualised strategies to achieve them. It is argued that comparison feedback may lead households with higher consumption to reduce their consumption, however, households with relatively low consumption may increase their consumption (Abrahamse et al. 2018). This is presumably because the social comparison made it clear that low-consumption houses had some room to increase usage in comparison to other households with higher resource use.

5.4.3. Reward in the Form of Shape Change rather than Extrinsic Rewards

Wemyss et al. (Quintal et al. 2013) stated that visual technology should neither reward nor punish the users, but it should keep them interested. Our findings partially justify and partially contradict this statement as we discovered that households preferred to be rewarded for good conduct, however, they do not want to be punished for high-consumption practices. This merits further studies to discover the fine balance between providing

accurate information and positive reinforcement as negative reinforcement could discourage people. It is argued that future work could further investigate how a system could promote sustainable practices through the influence of an extrinsic motivator for long-term engagement (Stegers et al. 2022). However, extrinsic motivations, such as rewards and incentives, are effective but only last as long as the incentive or penalty exists or is substantial, but intrinsic motivations are resilient and long-lasting once triggered (Bartram 2015). Participants interpreted the flower's blooming in the 'moving flower low-fidelity paper prototype' (Figure 1) as a reward. Therefore, investigating the design of a shape-changing visualisation that rewards the user through its change of shape may encourage households to take pro-environmental actions.

5.5. Reflections on Study Design - Future Directions

Our study did not use a large representative sample of UK households, however, it is not unusual for qualitative research to employ sample sizes similar to that used in our study (Caine 2016). Nevertheless, future research may benefit from replicating the current research using a larger sample of UK households to assess whether the current findings are replicated. However, the aim of this research is not based on generalisability but to understand the contextual household practices and experiences. Despite the fact that we recruited participants through the university network, our participants had diverse backgrounds and experiences, and a range of family sizes, locations, and socioeconomic status. Furthermore, three families (not affiliated with the university) were recruited through snowball sampling, in which existing participants assisted in identifying and referring additional participants. A varied selection of participants from various backgrounds, socioeconomic statuses, cultures, and viewpoints could benefit future work.

6. CONCLUSION

This paper discussed the importance of understanding household dynamics and experiences interwoven into a home while negotiating preferences and expectations of visual design considerations to reduce household consumption. Complementing the literature, we found that using shape-changing visualisations, empathetic and aesthetically pleasing visuals, designing for peripheral interaction and designing for a focal point in the home, and maintaining simplicity in the information display are useful considerations in creating home-based visualisations. We found that users get demotivated by negative feedback and ignore the visualisation. Goal-setting may be a better motivating strategy in contrast to competition and comparison while also providing a reward through the change of shape in the object may encourage households to perform pro-environment activities. We position the paper to contribute to the emerging discourse on designing HCI technology for household consumption reduction and collaborative design approaches.

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