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Carbon Footprint Interaction Through Slow Design Computing and Visual Design

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ABSTRACT

In the realm of human-computer interaction, the concept of user behavior change is gaining traction. This seeks to enhance product eco-friendliness and sustainability. 'Slow design' is one of the design approaches that steers products towards sustainable design. Our study applies slow design principles to carbon footprint calculation, creating more aware and visible interactions. This spurs user engagement in personal carbon auditing, fostering positive carbon reduction experiences. Through slow design and human behavior insights, we explore the potential for carbon assessment via records of six participants. Our findings inform future sustainable development studies. We introduce the Carbon Bubble Calculator (CBC), designed considering (1) behavior records, (2) social interactions, and (3) increasing awareness of reducing carbon emissions. These outcomes aid future sustainable development research.

Keywords: Carbon footprint, Slow design computing, Visual design, Human-computer interaction

INTRODUCTION

In human-computer interaction, the focus on 'user behavior change' grows, targeting greener, more sustainable products. The United Nations' Sustainable Development Goals (SDGs) have been a global call to action since 2016 (United Nations, 2015). These goals stress the interdependence of poverty eradication and strategies like economic growth, education, health, and environmental protection.

The pursuit of this goal has sparked the creation and use of numerous platforms and apps for calculating carbon footprints. These tools allow users to gauge their impact on the environment and receive suggestions for sustainable living based on long-term data. In the realm of sustainable design, the concept of 'slow design' also plays a role. Coined by Fuad-Luke (2005), it advocates a decelerated approach in contrast to the fast-paced consumption culture. Slow Design prioritizes quality, details, and experiences for meaningful and sustainable solutions, standing against instant gratification and excessive consumption.

However, obtaining a carbon footprint differs from acquiring information like daily caloric intake or daily expenses. Our recording habits for calories consumed from food or expenses incurred while purchasing items have been established for years. What sets these apart even more is that we can physically interact with calories – through food – and money when buying products, whereas carbon emissions remain beyond the foreseeability of the naked eye. As a result, we endeavor to apply the principles of slow design to the design research of calculating carbon footprints. Specifically, our aim is to create more "conscious" and "visible" forms of interaction, motivating users to actively engage in carbon auditing and derive more positive experiences from it. Through the application of slow design, we aspire to enhance users' emotional connection to this interactive behavior, thereby yielding sustainable benefits (see Figure 1).

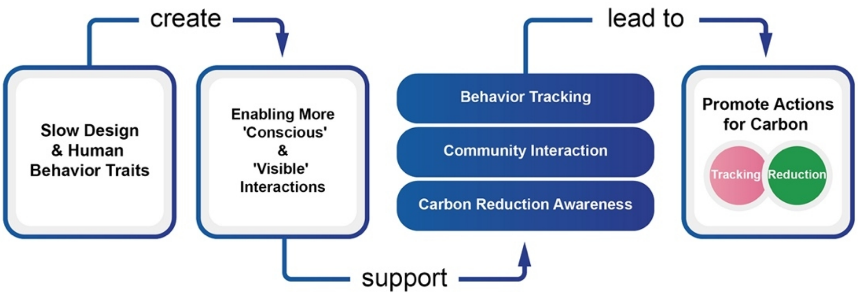

Figure 1: The design problem and design objectives.

BACKGROUND

Three Distinct Factors

Fogg, a professor of Human Behavior at Stanford University, introduced a pioneering model known as the FBM, offering a fresh perspective on comprehending human behavior (Fogg, 2009a). Within this model, behavior is conceived as a convergence of three distinct factors: motivation, ability, and triggers. Each of these factors encompasses a range of subcomponents (see Figure 2). The FBM framework asserts that, for an individual to engage in a desired behavior, they must possess (1) adequate motivation, (2) the requisite ability to perform the behavior, and (3) a triggering event that propels the behavior into action. Importantly, all three factors must align concurrently, or the behavior will remain unrealized. This framework provides a shared platform for considering and conceptualizing patterns of behavior change, making it a valuable asset in the context of research and discussions.

After reviewing design works from students and companies, he identified one prevalent reason for the failure of certain designs—overambition. For instance, design teams might opt for a challenging behavior, like quitting smoking, as their design goal. While the idea of aiding people in quitting smoking might seem noble, the reality is that for long-term smokers, designing behavior without enduring impact, coupled with a lack of relevant design expertise on the part of the team, inevitably leads to failure. Fogg recommends a strategy of achieving success by building upon numerous small, measurable victories before tackling larger endeavors (Fogg, 2009b). This approach ensures a solid foundation of achievements and aligns with practical, attainable goals.

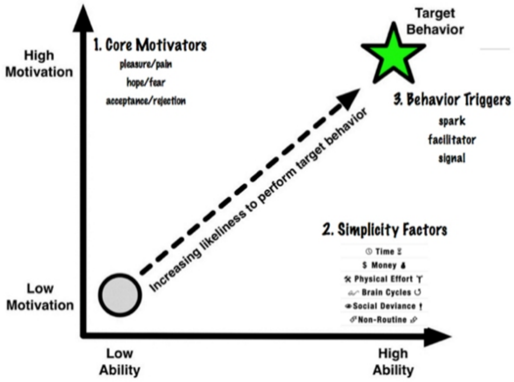

Figure 2: All three factors in the Fogg behaviour model have subcomponents (Fogg, 2009a).

Slow Technology Design

Hallnäs and Redström (2001) propose that as technology becomes increasingly integrated into our lives, its role transcends mere efficiency enhancement. They advocate for a shift in designers' perspectives towards creating "technology that surrounds us and becomes part of our lives for an extended period of time." They introduce the concept of "Slow Technology," which aims to evoke a heightened sense of the passing of time in everyday life, emphasizing gradual and subtle moments of the present. Their work emphasizes the potential for reflective experiences when this gradual approach is applied within the framework of slow design. Consequently, slow technology exhibits an accumulative nature that emerges not solely from isolated interactions but from the continuous accumulation of experiences.

While the visionary concept of slow design holds promise, its abstract nature poses challenges for practical implementation by designers and researchers. To address this, Odom et al. (2021) merged slow technology with tool analysis to propose a structured framework. Odom and his team initially (1) formulated a working definition of slow technology by drawing from early research and literature. Subsequently, (2) they selected a specific group of physical objects for analysis and (3) meticulously examined their potential attributes related to "slowness." The objects included Slow Doorbell, Photobox, Olly, Slow Game, CrescendoMessage, Olo Radio, and Chronoscope. (4) The team connected these attributes with the initial definition, and (5) iterated through steps 3–4 until each analysis became more aligned with the concept of slowness. Finally, (6) they critically reviewed the initial theory, expanding it based on their findings.

Slow Design Computing

Chang and Wu propose integrating slow design with computational methods, utilizing its principles and values in the realm of computer science and digital technology (Chang et al., 2020). This approach seeks to explore individuals' life trajectories and shed light on unseen issues.

Inspired by Kuang and Fabricant's work (2020), in "User Friendly", they reveal that climate change can be a feedback problem due to its inconspicuous nature. They state, "*We don't know how much carbon we emit every day... which makes the effects invisible. Imagine, for instance, that the effects of carbon emissions were exactly the same as they are now, except that the accumulation of carbon turned blue into green. In a world like that, it's hard to imagine anyone discussing whether human activity has any impact on the climate...*" We endeavor to visualize carbon footprint data and amalgamate theories and methodologies from figures like Hallnäs and Odom. Through the application of slow design computation, we aim to investigate the matter of personal carbon accounting (see Figure 3).

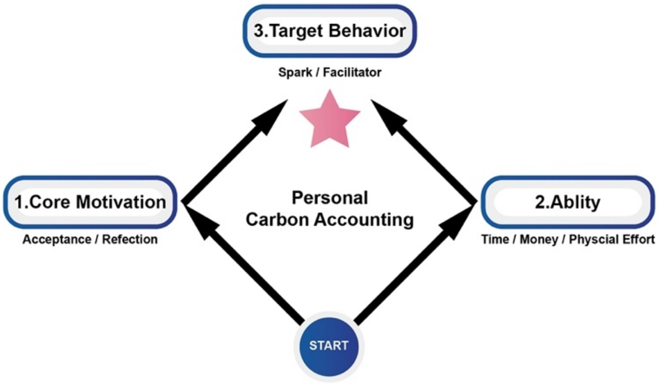

Figure 3: Three factors in personal carbon accounting of this study.

RELATED WORK

We reviewed relevant literature and cases, offering insights for future sustainable development research. Carbon footprint assessment methods vary, from spreadsheets to mobile apps. Existing global calculators like Global Footprint Network (2021) and United Nations (2015) cater to wide audiences. Nation-specific tools like Finland's lifestyle test (Sitra, 2021) exist. In Taiwan, we have platforms like Carbon Footprint Information Platform (Environmental Protection Administration, 2023). Enterprise-focused tools are exclusive. Our study enhances user engagement and awareness in carbon auditing.

We applied the principles of slow design to carbon footprint calculation using a method that blends creative ideation and semantic analysis, influenced by Odom et al. This approach involves integrating gamification into the design, creating two behavior modes to enhance user interaction. We explored how gamification can bridge the awareness-behavior gap in carbon footprint calculators, as demonstrated by Biørn-Hansen et al. (2022). This combination fosters meaningful user engagement and promotes sustainable behavior change (see Figure 4).

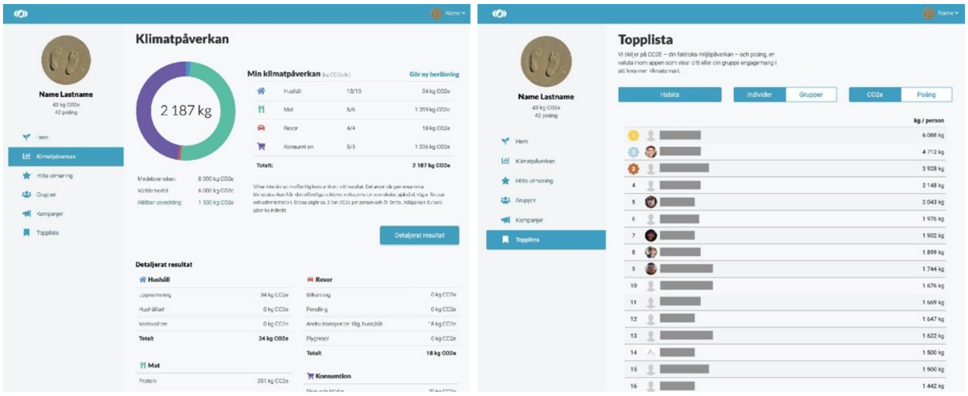

Figure 4: Carbon footprint calculators with gamification (Biørn-Hansen et al., 2022).

JORO (COMMONS, 2019) engages users post-login with questions regarding their daily carbon footprint elements, such as meat consumption frequency, household size, and air travel habits. Based on user responses, the platform offers tailored carbon reduction strategies, like shifting from daily to 4–5 times weekly meat consumption. Beyond offering concrete advice through consumption behaviour surveys and habit tracking, JORO recommends relevant carbon reduction courses and articles to enhance users' strategies effectively. Moreover, JORO integrates with users' credit cards to estimate carbon footprints per transaction. For instance, a $100 expenditure at Whole Foods or a prior survey indicating 3–4 times weekly meat consumption enables JORO to calculate user-specific carbon emissions (see Figure 5).

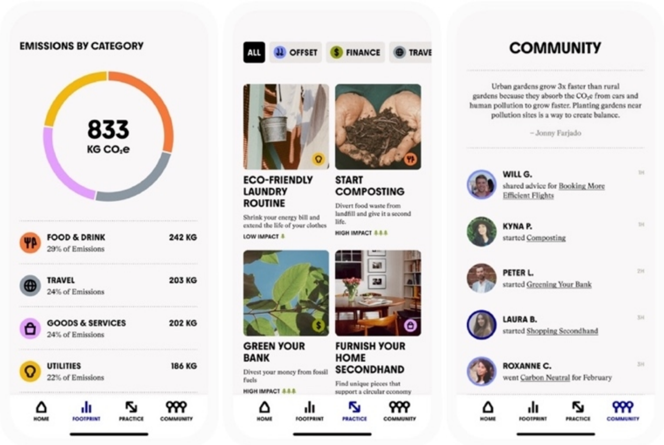

Figure 5: The user interface of JORO (COMMONS, 2019).

CARBON FOOTPRINT INTERACTION

We introduce the Carbon Bubble Calculator (CBC), which visually links carbon emissions to bubble imagery, symbolizing their generation, attachment, and release. This approach fosters a more 'conscious' and 'visible' interaction, enabling users to see their accumulated carbon footprint. This encourages ongoing engagement and positive experiences, extending beyond one-time calculator use. Next, we present our research extrapolation.

Persona

We initially recruited 6 participants from diverse fields to gain insight into their awareness of carbon emissions. Through surveys, users were prompted to record aspects of their daily lives, encompassing: (1) time allocation, (2) behaviors related to food, transportation, accommodation, leisure, education, and other categories, and (3) duration of these activities. The participant profiles and recorded activities are detailed in Table 1 as follows:

Table 1. Participant's activity records.

Name	DAVID (male, 30 years old)		
Description	David is a computer engineer residing in Taipei City. He typically commutes to work in the morning by riding his motorcycle or taking the subway. He buys breakfast on his way. For lunch, he dines at restaurants near his workplace. In the afternoon, he walks home after work and buys a drink on the way.		
Time	**Behavior**	**Describe**	**Remark**
00:48-07:50	Sleep	used air conditioning, electric fan	-
08:10-08:25	Work	subway commute	2 stops
08:30-08:33	Breakfast	takeaway sandwich, large iced latte	sandwich comes with packaging, personal reusable cup used for coffee
12:20-12:50	Lunch	dine-in Hainanese chicken rice	given disposable chopsticks and spoon set, plus four tissue paper sheets
18:20-18:50	Dinner	dine-in minced pork noodles, blanched greens, deep-fried braised pork	no use of disposable utensils
19:36-19:39	Beverage Purchase	fresh milk tea, low sugar, light ice	used a personal reusable cup
19:45-20:05	Bicycle Ride	Ubike (shared bicycle)	approximately 1 kilometer
08:00-20:00	Walking	accumulated walking from08:00-20:00	1 hour and 18 minutes
20:30-00:48	Rest	used computer, air conditioning, electric fan	3 hours
20:30-00:48	Showering	Showered, blow-dried hair	42 minutes
00:48-	Sleep	-	-

During our attempt to collect questionnaire responses, we identified some noteworthy issues. Initially, participants seemed to associate carbon emissions mainly with transportation. To address this, we explained various carbon-producing factors early in the questionnaire collection, enabling a more comprehensive grasp of carbon emissions and facilitating broader data collection. Additionally, due to Taiwan's "plastic reduction policies," promoting reusable cups for beverages, participants often brought their own cups. However, this behavior wasn't consistently reflected in their recorded actions. Lastly, participants' lack of training in creative or concise thinking led them to describe daily behaviors in complete sentences rather than breaking them down into smaller actions, limiting the use of succinct vocabulary for recording purposes.

Data Cleaning

Based on the collected data, we analyzed participants' questionnaire logic, calculated emissions using the carbon footprint formula, and generated a preliminary.txt file. The data formats adhered to different standards (Corporation, 2023; Environmental Protection Administration, 2023). Our research found that walking has a carbon emission factor of around 0, indicating it doesn't directly emit carbon. We focused on its indirect impact: reducing the use of other transportation modes. The reduction in emissions depends on the activities participants chose while walking, like avoiding cars or other vehicles. After data organization, we compiled the following list:

Table 2. Participant's activity records.

No	Time	Describe	Duration	Unit	Carbon Emissions(kg)
1	00:48-07:50	air conditioning	7.2	hour	2.3166
2	00:48-07:50	electric fan	7.2	hour	0.171072
3	08:10-08:25	subway commute	2.4	kilometer	0.096
4	08:30-08:33	sandwich	1	disposable packaging	0.69
5	08:30-08:33	iced latte	1	Eco-friendly cup Eco-friendly straw	(0.0032) (0.00533)
6	12:20-12:50	disposable chopsticks	1	pair of	0.05
7	12:20-12:50	disposable spoon	1	a	0.00603
8	12:20-12:50	tissue paper	4	sheets of	0.015
9	19:36-19:39	fresh milk tea	1	Eco-friendly cup Eco-friendly straw	(0.0032) (0.00533)
10	19:45-20:05	Ubike	1	kilometer	(0.096)
11	08:00-20:00	walking	78	minute	
12	20:30-00:48	air conditioning	3.2	hour	1.0296
13	20:30-00:48	electric fan	3.2	hour	0.076032
14	20:30-00:48	showering	30	minute	0.0483
15	20:30-00:48	blow-dried hair	0.2	hour	0.099
			Total 4.484574		

Carbon Bubble Calculator (CBC)

Based on the recorded behaviors in participants' questionnaire responses, this study designs three behavior patterns and one interactive visualization using (1) behavior tracking, (2) social interaction, and (3) increasing awareness of reducing carbon emissions. Expanding on Fogg's FBM model, we establish three sets of behavior models and a single interactive visual model.

- Record Mode

  The aim is to establish a "Carbon Ledger" and database that facilitates a thorough and accessible process for carbon auditing. The recording pages consist of three methods. The first involves entering carbon emissions data retrieval, presenting five selectable options, such as food, transportation, accommodation, entertainment, and education. The second method entails scanning carbon emission barcodes, while the third method involves rapid addition.

(1) **Method 1: Carbon Emission Retrieval.** This records previously scanned carbon emission barcodes and swiftly adds carbon information. As we observed participants' routines, this method is designed to facilitate the quick addition of past records, enhancing user motivation and fostering the incorporation of recording into daily habits.

(2) **Method 2: Barcode Scanning.** Users can quickly import carbon data by scanning barcodes with their mobile phones. Inspired by Taiwan's established "invoice consolidation" practice and future postal plans for carbon data recording, this approach utilizes mail barcodes to enhance data recording, including factors like mail weight and delivery distance.

(3) **Method 3: Quick Addition.** If carbon data is not yet available in the carbon emission retrieval or barcode scanning options, users can create carbon data through the quick addition feature.

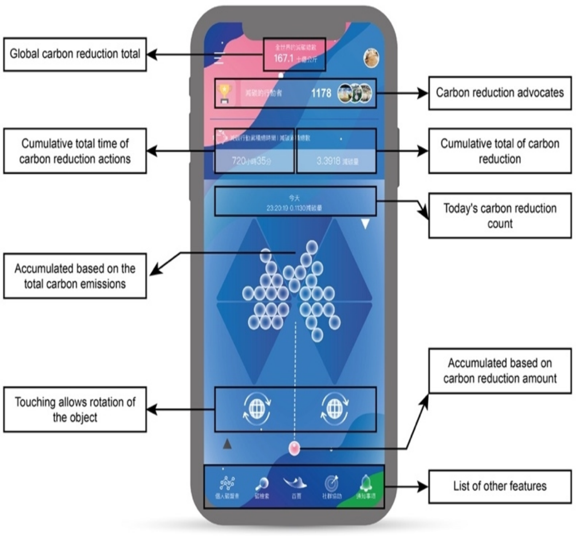

Figure 6: Domains of human systems integration.

- Bubble Mode

  This mode creates bubbles from users' carbon emission records, which accumulate in a pentagon representing five lifestyle categories (food, transportation, accommodation, entertainment, education), with bubble quantity determined by daily cumulative carbon emissions (see Figure 6).

(1) **Carbon Attachment.** Using Participant 's activity records as an example, with a cumulative carbon emission of 4.484574, Participant generates 4 carbon bubbles on that day. These 4 carbon bubbles will be positioned within the pentagon, attached to the most frequent carbon-emitting behaviors, such as food and accommodation.

(2) **Carbon Reduction Burst**. Users' carbon reduction actions, like using reusable cups or walking, are calculated to generate burst orbs based on accumulated reduction values. CBC's carbon reduction design encourages users to adopt small changes, building reduction capabilities, accumulating values, and fostering a sense of achievement that becomes habitual.

Using Participant A's records, they accumulate around 0.11306 units of daily carbon reduction, significantly lower than their carbon emissions. To address this, we accelerated burst orb accumulation by 10 times. When a burst orb forms, users can opt to break a carbon bubble within the pentagon.

- Community Mode

  When any of the triangles is filled with bubbles, the accumulated bubbles within that triangle are cleared. The system then registers a failure and affects the ranking in the Community Mode.

(1) **Friend Burst.** We recognize that while some individuals might be passively reducing carbon, others are doing so actively. For instance, if any triangle in User B's profile is nearly full, CBC sends User B's friends a notification. If User A generates a carbon bubble that day, they can place it in their own pentagon or in User B"s to help them out.

(2) **Exploration Capability.** In this mode, we encourage users to discover minor lifestyle changes. The rule is to project carbon bubbles into the corresponding triangle fields. For instance, if User A's carbon bubble comes from reducing food and transportation emissions, it can only be projected onto those fields in the Community Mode.

CONCLUSION

This study explores the potential for carbon auditing by examining behavior records of six participants through the lens of slow design and human behavioral characteristics. The findings serve as reference for future sustainable development goal studies. The introduced Carbon Bubble Calculator (CBC) is designed with (1) behavior tracking, (2) social interaction, and (3) increasing awareness of reducing carbon emissions, linking the generation, attachment, and burst of bubbles through carbon emission increments and reductions. This visualization enhances "conscious" and "visible" interaction. The model was further refined through low-fidelity prototypes and task testing with the same six participants (see Figure 7).

Participants found that the CBC effectively helps them assess their carbon footprint, making carbon tracking seem easy while carbon reduction challenging. While linking emissions to bubbles and community interaction sustains the habit, forming a personal carbon auditing habit requires longer-term efforts. Nonetheless, applying slow design principles in carbon footprint design creates conscious and visible interactions that motivate users to actively engage and derive positive experiences from carbon auditing.

Figure 7: Simulated usage scenario of CBC by user.

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