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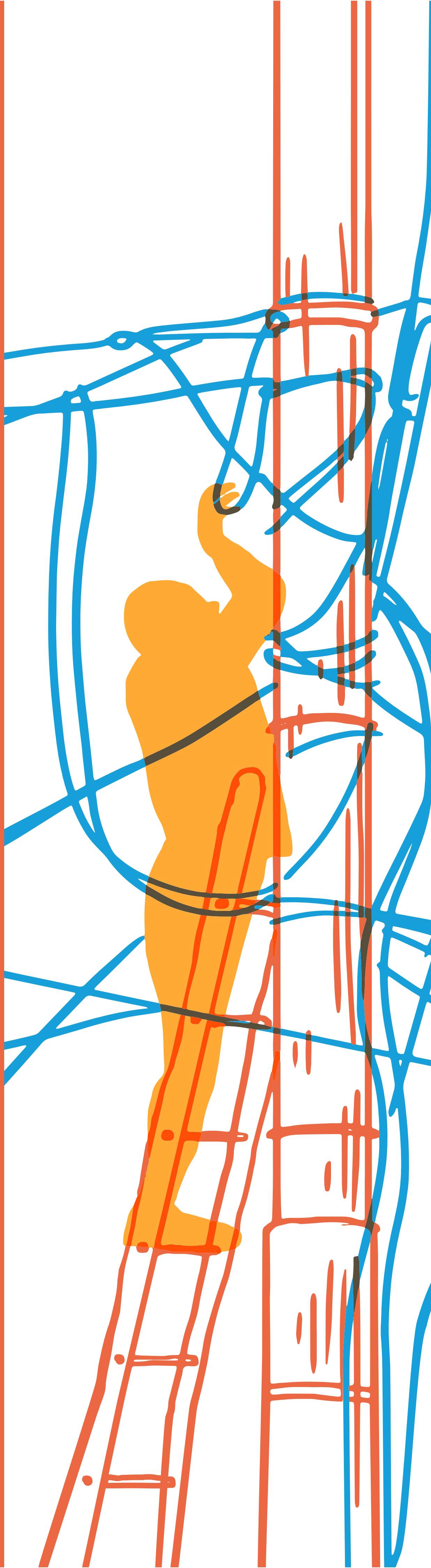
Entanglements and Flows
Service Encounters and Meanings



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Larissa Farias, Manuela Quaresma

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UX Sustainability: an overview on the sustainability dimension of AI-infused Objects forming product-service ecosystems

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Abstract

This research aims to suggest a new design perspective to analyse the sustainability of an AI-infused object in its entirety. Before we present what AI-infused Objects are and how they form product-service ecosystems, secondly, we analyse the state of the arts of its sustainable dimension. The analysis of AI-infused objects should include: (1) the entire life cycle of the object, its social and economic impact; (2) the impact of the "digital soul" of the object; (3) the ecosystem analysis should also include all indirect impacts of the service, considering how users' behaviour changes when they come in contact with the artificial intelligence ecosystem. The research contributes to the design literature in two ways: (1) by raising awareness in designers on the effective impact of AI-infused Objects forming the product-service ecosystems, (2) by inviting designers to make this awareness concrete through User Experience Sustainability analysis and behavioural change strategies applied to persuasive technology.

Keywords: Sustainability, User Experience Design, Artificial Intelligence, Life Cycle.

Introduction

Digital technology is being integrated into various scenarios and processes of our industry and society, primarily by creating services to support people. Indeed, service delivery is increasingly accompanied by a series of physical touchpoints, but with a digital 'soul', which in recent years has initiated the digital transition of most services, creating a true ecosystem of digital touchpoints. Illustration of digital services with physical touchpoints are AI-infused objects, an example being Alexa, the access point to Amazon's services, or the smartwatch, which supports users throughout the day, giving them feedback on their health condition. Digitisation and its impact on value-creation processes have been actively discussed in services research (D'Emidio et al., 2015; Toivonen & Saari, 2019). The aspects to be assessed and quantified related to the rapid advancement of the digitisation process are not few. The digital ecosystem underlying most of the services in use today is complex (if not impossible) to analyse in its entirety in terms of direct and indirect impacts. Following Brundtland's report definition of sustainability from 1987: when exploring the sustainability of a service, one should examine the service's economic impact, social impact and environmental impact and its consequences in terms of material, digital and human components. These dimensions of the service should be considered in an ecosystemic manner during the design of the service. While on many fronts, research has already started to untangle some aspects of service sustainability - see, for example, the life cycle Assessment design proposed by Vezzoli in the sustainable product-service system (Vezzoli & Sciama, 2006; Vezzoli et al., 2017); the life cycle assessment of the AI dimension of a service done by Ligozat et al. in 2022 and the social life cycle of a service done by Watanabe et al. in 2021 -. These aspects have never been analysed simultaneously in a product-service ecosystem based on AI-infused Objects.

Finally, to complete the definition of sustainability, the analysis of a service also includes its lifecycle cost to understand what is feasible and its impact on the economy. However, considering the dimensions of environmental, economic and social sustainability is not exhaustive to obtain an ecosystem view of digital services' impact on our society. It is also necessary to consider how the service is used and the impact caused by the user's experience.

To date, User eXperience (UX) is seen as an operational or pragmatic dimension that is developed vertically. However, it has the potential to be applied to the whole process and has as one of its primary goals to provide a more sustainable experience of the whole object, from how it is created, to how it is used and then discarded. The research presented aims to understand how the sustainability dimension of an AI-infused object can be improved at the ecosystem level through better UX. The renewed role of design in defining UX sustainability in the ecosystem-level service system.

Contribution

This work firstly contributes to contextualising the importance of assessing the impact at the ecosystem level of an AI-infused object, taking into consideration the environmental, social and economic impact from the perspective of the systemic view of service design. Secondly, it highlights the possible strategies available to the designer to develop sustainable solutions.

Methodology

This study presents an experimental theoretical research, as the researcher wants to gather more information on the AI-infused object's sustainable dimension without be strict uniquely to its practical operation. Exploratory research is a preliminary study for topics on which more in-depth knowledge has not yet been explored. A study was conducted to understand the relationship between sustainability and the use of AI-infused Objects.

- The literature review pursued the following keywords in a logical order: - - Environmental impacts of AI,
- Evaluation of human behaviour in AI infused Objects,
- Methodologies currently used to investigate the environmental impact of AI-infused objects.

Most of the studies analysed come from the fields of engineering and sustainability. Secondly, from the field of psychology and lastly, from the field of design. The aim was to bring awareness to the design world of the state of the art of analysis applied to physical objects using artificial intelligence. The case studies analysed were only those from the last five years in the field of computer science to ascertain state of the art.

AI-infused object: what kind of service does it offer, and why need to be evaluated?

AI-infused objects are smart objects that possess Artificial intelligence. AI-infused objects are cyber-physical, networked, and are part of an ecosystem of intelligent objects (Vitali, 2021). In this ecosystem of objects, the user uses a service. The goal of these objects is to support human life in different situations and domains through data collected and analysed by artificial intelligence in order to help the user. AI-infused objects are physical objects with a digital representation (Agrò, 2018); they are networked and connect to other products using various wired and wireless communication technologies, forming an ecosystem of touchpoints with a ‘digital soul’ (Abramovici, 2014; Greengard, 2015). Their 'intelligence', understood as the ability to handle information or make decisions, can be located not necessarily at the device level (Meyer et al., 2009). Objects infused with artificial intelligence are a service to the user because smart products exhibit autonomous and proactive behaviour, giving the user ad hoc feedback and supporting them in activities with or without their awareness, e.g. autonomously changing the room temperature to make it more comfortable. They can continuously monitor their state and environment and have sensing capabilities (Vitali et al., 2022). They can often learn from experience and infer high-level patterns and events from the data (e.g. understand a specific user's preferences). This allows intelligent products to show forms of awareness and evolve their performance over time (Spallazzo, 2022).

For this reason, we can consider AI-Infused objects generically as a service with multiple touch points using artificial intelligence. This technology can acquire, analyse and remember data to provide personalised feedback to the user. This is the service that artificial intelligence usually offers to users as support during their daily life, fitting perfectly with the definition given by Foglieni et al. "Service is basically an activity performed by someone (or something) in order to give support, to satisfy someone else's need" (2017).

Having a method capable of evaluating the impacts of AI-infused objects at a systemic level is fundamental because its outcome becomes a tool for value creation and a driver for product innovation, identifying areas for project improvement (Foglieni, 2007). This is the purpose of evaluation: to understand how well or badly activities, projects, products and services work in order to better understand what is wrong and thus improve it (Bezzi, 2007). “A company that does not manage customer evaluation in the production of goods and services will not generate sales” (Holmlid, 2010). The same applies when one wants to develop an increasingly sustainable service.

Life cycle assessment (LCA) is the most widely used method to date to assess environmental impacts. *How could we apply LCA to AI-infused object components at an ecosystemic level?* Analysing the different elements of these types of service products, we can see that they are composed of (A) a physical and tangible component, which comes into contact with the user through interaction on different devices, the 'body'. (B) A 'digital soul' that animate the service behind the objects through the collection, analysis and storage of data and the redistribution of the data to the different touchpoints in the object ecosystem to return useful feedback to the user. (C) The human component, how the user interacts with the object and how their behaviour changes before and after contact with the service provided by the object ecosystem.

A: Methodologies to assess a service impact and its variants

The most widely used impact methodology is Life Cycle Assessment (LCA), a methodology for assessing the environmental effects associated with all stages of a product, process or service life cycle (Ilgin et al., 2010). (See table 1)

LCA phase	Phase description
Raw material extraction	includes all industrial processes involved in the transformation of the material
Production	includes the processes that create the Product/service from the raw material
Transport	includes all the transport processes involved, including the distribution of the Product/service
Use	which mainly includes the energy consumption of the Product/service during its use
End-of-Life	which refers to the processes of dismantling, recycling and/or disposal of Product/service.

Table 1. LCA common analysis phase of AI Infused objects

According to ISO 14040/44, an LCA generally comprises four steps: goal and scope definition, inventory analysis, impact assessment and interpretation. It also requires the definition of a system boundary and a functional unit to create a comparative assessment of the results obtained (International Organization for Standardization, 2006).

Integrating environmental requirements into the design of a service means dealing with increased complexity, a large amount of information and relationships with stakeholders from different disciplines (Vezzoli, 2017). Design must adopt a systemic approach to all product life cycle phases.

This includes the pre-production, production, distribution and use of the product - which includes both the consumption of the resources required for its operation and the related processes (such as maintenance) and the decommissioning of the product. The life cycle described can be defined in environmental terms, considering the inputs and outputs of the processes of each stage on the geosphere and biosphere and assessing the environmental effects these inputs and outputs cause.

Some of the effects that should be assessed and quantified are resource depletion, the greenhouse effect, ozone depletion, eutrophication, smog formation, acidification, toxins in the air, water and soil, and the amount of waste produced. These are just examples, then depending on the type of service and company, the direct environmental impacts to be assessed may be different.

In this scenario, the designer's role in the LCA is to reduce the material inputs involved in the process and energy, as well as the impact of all emissions and waste in both quantitative and qualitative terms.

There are two different approaches to assessing environmental impacts from a lifecycle perspective: attributional LCA (ALCA) and consequential LCA (CLCA). Both approaches pursue the assessment of environmental impacts along the life cycle, they differ in terms of process modelling, multifunctional process management and scope of the study (Ekvall, 2019). An attributional approach aims to quantify a product's or service's environmental impacts along the life cycle with average processes, i.e. emissions are allocated equally to processes. In contrast, a consequential perspective uses marginal processes that describe the marginal change in emission factors, focusing on the system-wide consequences caused by the implementation of a given product or service. According to the definition, CLCA is a form of LCA to describe how environmentally relevant flows will change in response to possible decisions (Ekvall, 2019). This approach requires more extensive modelling at the system level and is, therefore, more comprehensive than an LCA. In the current state of research, there is a tendency to analyse the LCA of service from only one of the two perspectives when in fact, both are necessary for the sustainable development of a service.

The most common practice to assess the LCA of a service mainly considers direct attribution impacts. Similarly, it usually leaves out the social and economic impacts of the service. Additionally, the impact of artificial intelligence and user behaviour change must be considered.

Rephrasing Vezzoli (2017), when evaluating and designing a service, designers must refer to the function offered by a given product, the so-called functional unit. In our case, applied to a system using artificial intelligence, it is also noteworthy to evaluate technology's effect in guiding user behaviour towards a more sustainable general attitude.

What should be further integrated into LCA in practice

The LCA process seems comprehensive in theory, but it has some unresolved issues in practice. Firstly, LCA analysis tends to consider only the environmental impact of a product, leaving out the economic and social impacts of the product's production, use and disposal process.

Early advances in sustainable design stemmed from the desire to reduce environmental impact during the life cycle. However, today a more comprehensive focus on all three aspects of sustainability has developed: environmental, economic and social (Larsen et al., 2022), but studies on objects with a technological soul considered systemically are still not to be seen in the literature. Most studies still focus on only one of the three aspects. Furthermore, there seems to be a growing, but not exhaustive, focus on understanding the use of a product in all its details. The difficulty of collecting real data causes the challenge, but thanks to advances in telematics systems applied to products, it is now possible to collect real-time data on product usage (Kim et al., 2020). While the optimal use of resources now seems to be an established direction in sustainable design approaches, the integration of data and analysis, user and usage understanding, and lifespan management are emerging research fields with the potential to incorporate the use phase into sustainable design fully.

Finally, research on defining system boundaries and perimeters is essential to make environmental impact assessments more reliable, especially when dealing with increasingly complex systems (Kim et al., 2020).

Life cycle sustainability assessment, presented by Kloepffer in 2008, is less widely used in a practical way but encompasses all three pillars of sustainability: social, economic and environmental, also integrating Social life cycle assessment (S-LCA) and Life Cycle Cost (LCC).

Social Life Cycle Assessment (S-LCA)

Social Life Cycle Assessment (S-LCA) is a method that can be used to assess the social and sociological aspects of services, their actual and potential positive and negative impacts along all stages of the life cycle.

The S-LCA does not assess whether or not a product should be produced, but usually, the analysis provides insights into the decision-making process during the production of the service. Usually, S-LCA is complementary to LCA and LCC (life cycle cost).

The UNEP Guidelines for the Social Life Cycle Assessment of Products propose a methodology to develop life cycle inventories. A life cycle inventory is developed for indicators (e.g. the number of jobs created) linked to impact categories (e.g. local employment) covering five main stakeholder groups (e.g. workers, consumers, local community, society and value chain actors), UNEP guidelines are the most adopted in the literature (Tokede & Traverso, 2020).

Furthermore, S-LCA involves stakeholders in defining the objectives and scope, collecting and interpreting data, which is different from both LCA and LCC. Examples of indicators in S-LCA are sustainable behaviour, health, safety, casualties, human rights, accountability, architectural quality, architectural diversity, added social value, future value, historical continuity, cultural heritage, governance, socio-economic impacts and labour policies (Larsen et al., 2022). So far, there is no consensus on the selection of impact categories, nor are there harmonised methods or frameworks for conducting S-LCA (Liu et al., 2019). To the best of the author's knowledge, S-LCA has not yet been included in the world of AI-infused object assessment.

Life Cycle Cost

Life cycle cost (LCC) is an approach that assesses the total cost of an asset over its life cycle, including initial capital costs, maintenance costs, operating costs and the asset's residual value at the end of its life. The assessment of all environmental (LCA), economic (LCC) and social (S-LCA) benefits and negative impacts in decision-making processes are calculated in the LCSA (life cycle sustainable assessment), with a focus on more sustainable products and projects over their life cycle (Larsen et al., 2022).

The LCSA has the potential to gain an ecosystem perspective in decision-making, assessing the social, economic and environmental effects of a decision. In this way, LCSA can highlight situations where the Circular Economy may be too narrowly focused on the 'circularity' of a specific resource and where a specific circular strategy can be evaluated from a broader sustainability perspective (Peña et al., 2020). Such evaluations are done and used mainly in engineering disciplines. However, they are still poorly adopted and need to be further deepened from the design perspective in order to turn the awareness gained by the LCSA assessment into actionable solutions.

B: The impact of the digital soul in AI-infused Object

The environmental impacts of the infrastructure supporting the ‘digital soul’ vary depending on the scope and use case. Current studies distinguish between direct effects that consider energy demand or emissions directly associated with the life cycle of components, indirect effects assess impacts beyond this system boundary. Recent studies divide indirect effects into positive (enablement) or negative (rebound) effects associated with new services or products (Coroamă et al., 2020; Wohlschlager et al., 2021). These effects can be considered both at the household level, such as the change in consumption patterns and at the system level, such as the impact on the integration of renewable energies. The literature in the field of ICT regarding rebound effects shows numerous possible implications and the need for transdisciplinary methodological approaches such as behavioural research (Kaack et al., 2022). With regard to smart meters and in particular flexibility mechanisms, the novelty of the analysed use case and the lack of empirical data currently hinder the quantification of rebound effects.

This possibility, however, is well known to the scientific world. In fact, several studies have been carried out to analyse the impact of artificial intelligence. However, they are mainly carried out in the world of engineering. They are little shared with those who make the technology usable for the user, the designers, who are in charge of making technological objects usable.

The literature on AI mostly deals with a small part of the direct impacts and neglects the technology's production, end-of-life, and possible indirect effects. In Wu et al. (2022) and Gupta et al. (2022), the authors point out the methodological shortcomings of previous studies, focusing on the utilisation phase. Lacoste et al. (2019) and Kaack et al. (2022) elaborate on the carbon emission sources of an artificial intelligence service, offering a more comprehensive view of the direct impacts in terms of carbon footprint. In addition, the latter also argues the need to consider indirect impacts (e.g. behavioural or social changes due to AI) when evaluating AI services.

Ligozat et al., (2022) have shown that the current environmental assessment of AI services is underestimated; AI for Green documents only consider a small fraction of direct environmental impacts. Several reasons can explain this underestimation. Narratives about dematerialisation, which would correspond to a drastic reduction of environmental impacts, permeate AI as part of ICT. However, these narratives have so far proven to be false (Ligozat et al., 2022). AI's greenhouse gas emissions have focused on electricity consumption (energy flows). While instead, material flows receive less attention in AI. However, they are beginning to be considered (Wu et al., 2022 & Gupta et al., 2022).

The designer and AI: a difficult choice

The designer must understand the direct and indirect impacts of artificial intelligence to discern when it is appropriate to adopt AI in an AI-infused Object and its consequences.

One of the most obvious impacts is the one caused by the energy required to keep AI alive. Often AI is used and associated with a sustainable solution; for example, an AI system that manages the lights in a building is usually considered sustainable because it is not subjected to the human error of leaving the lights on; however, how often do we actually forget the light on? The trade-off of having a system training constantly on our habits to provide us with the best experience of when we need a light perhaps pollutes more than the few times we risk forgetting the lights on. Indeed, in the field of AI, it is common practice to maximize computation cycles to improve performance, according to the belief that 'bigger is better': the systematic collection of more data and the use of more computation cycles until a better result is achieved has led to a sharp increase in energy consumption (Crawford, 2021). Since 2012, the amount of computation used to train a single artificial intelligence model has increased tenfold yearly: developers 'repeatedly find ways to use multiple chips in parallel and are willing to pay the economic cost' (Cook et al., 2017). So knowing the actual impact of the presence of AI in a product or service is also critical from a strategic perspective for the producing company, as AI has both an environmental and economic cost to be maintained.

The impact created by user behaviour:

The designer should also consider the domestication process of the technology and how it might modify its impact in our society. An example is "rebound". Rebound refers to the consumption of a specific product based on how the price of a product affects its demand. All efficiency and substitution benefits obtained from ICT will experience some level of direct rebound. Shehabi (2017) provides a clear example that explains the dematerialization paradigm: the growth of streaming video forms an energy-efficient form of viewing, compared to going to the cinema or renting a DVD, but the ease of viewing with streaming can lead to watching more movies, ultimately reducing the net efficiency benefits. Shehabi (2017, p. 176) reminds us that "the impact of direct rebound is limited by saturation. Regardless of cost or ease of purchase, people will no longer watch movies".Additionally, indirect rebound impacts consider the impacts of what could be done with the extra time or money gained through ICT efficiency or replacement. Spending less time and money watching a streaming movie at home rather than going to the cinema means that people will have more time and disposable income to buy other goods and engage in other activities that may have more or less environmental impact than the original trip to the cinema that was avoided.

The political impact of AI

Although it is often not visible and seems like an almost “alien” force, artificial intelligence is tangible and made of human labour. When comprehensively analysing this technology, it is necessary to consider the human labour required to make artificial intelligence work, the role of data in businesses, workplaces, and our society, and the planetary resources consumed to build and keep artificial intelligence running. This impact is detailed by the work of Crawford (2018 and 2021). The human labour required to operate, overhaul, and train artificial intelligence is often dehumanizing and underpaid, composed of repetitive tasks to train AI that turn humans into machines.

Data also has an influence that cannot be underestimated; it is necessary to understand the role of data and track it to ensure it is not used for improper purposes. Data can also stimulate, generate or reinforce biases within our society.

Ultimately, the planetary resources to build AI environments and the mechanisms of exploitation and pollution that are set up where the raw materials that constitute AI are extracted. These are the political implications and reasons why designers must weigh well where to use and include AI.

C: User experience and the potential to create incrementally sustainable AI-Infused product

User experience has the potential to improve the sustainability dimension of objects with artificial intelligence. UX designers consider the interaction with the object from the user's perspective throughout the design process, rather than employing top-down 'engineering' strategies that often focus on technical solutions and ignore the real needs of stakeholders, with a more systemic approach to design (Norman, 1988). The remarkable aspect of UX is that the process is continuously iterative, which promotes constant change and updating of the product, even after it has been sold or released. In digital products, the software is updated through the 'cloud' or the Internet (Gothelf & Seiden, 2021). This process means that "design is never finished" (Jitkoff, 2016), pushing designers to offer the user an ever better version of the object.

Furthermore, this phrase suggests that designers have the power actually to change the product, hence Don Norman's call to be conscious of the products they create and to "go out and change the world by offering the right products" (Meyer & Norman, 2020). The user experience focuses on the hedonic qualities of an object. It is, therefore, about understanding what drives a user to interact with a digital product and what motivations, visions and values they have to satisfy their psychological needs.

User experience has the potential to create sustainable incremental innovations. The first step in creating sustainable innovations is to change perspective: for an object to be sustainable, one cannot only work on the efficiency of the product. As Hssenzahl (2021) points out, "we cannot solve the resource consumption problem and the social aspects of sustainability based on efficiency alone", but "technology must first and foremost be a positive experience for users". This means that if an experience is very efficient (and perhaps even sustainable) but meaningless to the user, the designer would have created a useless product because it would remain unused.

Sustainability should be considered as one of the actors in the user experience design process. As Verganti and Norman (2014) point out, User Experience, through its continuous iterative cycle of research, succeeds in proposing technological solutions that are ever closer to the interests of users and stakeholders. Systematically, UX succeeds in creating innovation on the incremental starting product. If sustainability were considered a stakeholder, then it would mean that we would be able to build more and more sustainable innovations.

Strategies to promote more sustainable user behaviour have already been studied and applied in the literature, one example being persuasive technology. The link between technology and sustainable user behaviour can be described by distinguishing four possible roles of technology

1. as an intermediary, where technology used to achieve a goal defines ecological impact, although it is often surrounded by uncertainty.
2. as an amplifier, where technology amplifies human potential to achieve goals while amplifying resource use.
3. as a determinant, where behaviour is shaped and activated by the technological environment's possibilities, constraints and directions.
4. as a promoter, where technology is designed to influence behavioural choices (Midden et al., 2007).

This underpins the persuasive technology of Fogg's model (2003), which virtually suggests strategies for digital product designers for effective behavioural change. In effect, designers must understand the critical behavioural issues they wish to change in their users; secondly, designers must consider the context in which the technology will be used to arrive at a persuasive strategy. Examples of persuasive technologies are eco-feedback systems, feedback customisation, user competition, simulation, etc.) Smartwatches are an example of persuasive technology and behavioural change. Indeed, by tracking steps, this technology can stimulate more physically active behaviour in the user, making the smartwatch more sustainable than its analogue predecessor. The designer, therefore, already has at disposal some theories of behavioural change, so if the latter were implemented within the UX, they could work as an enhancer of sustainability in products or services that do not have sustainable behaviour as their primary purpose, such as AI-infused Objects, where the primary purpose usually remains to support the user.

Conclusions

In this work, we provide an overview of the state of the art of sustainable dimension assessment applicable to AI-infused objects, explaining the research gap and why designers should be aware of the impact of the object being analysed. Life Cycle assessment is a well-known methodology for calculating objects and services' impacts. It is usually applied to investigate the direct environmental impact of services, but it is not exhaustive. Life cycle sustainability assessment, presented by Kloepffer in 2008 is less applied in practice but in theory includes all three pillars of sustainability: social (S-LCA), economic (LCC) and environmental. The S-LCA aims to verify the social impacts during all phases of the Object's life cycle, usually proposing a qualitative assessment. This type of assessment is not very frequent and, in fact, not well-established in the scientific world. To date, the only attempt to standardise the process comes from UNEP (Benoit et al., 2020). On the other hand, life cycle cost deals with analysing the cost to the company of each product stage, it is usually quantitative and is more frequently used than S-LCA.

To date, in the literature, some studies of LCA applied to smart objects are present, but they do not include LCC and S-LCA simultaneously and do not consider the impact generated by the AI of the AI-infused Object. In fact, the impact generated by the AI component is not marginal; in the literature, there are several studies focused on the analysis of the LCA of AI, but they usually do not consider the physical dimension of the Object using artificial intelligence and the change in user behaviour caused by the interaction with the AI-infused object.

AI is often associated with more sustainable solutions; examples are its adoption in the decision-making process to choose the most sustainable materials or to optimise food production and avoid waste. While fewer studies focus on the environmental impact caused by AI itself, its 'hunger' for data and the energy consumed to train this technology, and return the ad hoc feedback to the user. In addition, the political impact of this technology is not negligible, as explained by Crawford's work (2018, 2021): AI is made of human labour, often dehumanising and composed of repetitive tasks; AI uses data that is often misused by big corporations and it can create or reinforce prejudices in our society.

Not least, the indirect impacts of AI, such as the rebound effect and the dematerialisation paradigm. AI underpins many digitisation processes in our society and radically changes consumer and market logic. It is the designer's task to act on the possible behaviours to be changed in the user while using the AI-infused Object. This is the designer's role to be aware of the digital (and not only physical) impact of an AI infused object, to make this impact more visible within the company with the aim to create a framework of shared value and to identify and orientate projects towards more sustainable solutions. The designer in addition, thanks to the presence of AI in the AI infused Object, has the possibility of accessing usage data and of modifying and updating the Object even after it has been sold via the "cloud." By analysing the UX of the AI infused Object, the designer is able to apply behavioural change strategies with the intention of steering user behaviour in more generally sustainable directions, creating a Sustainable UX.

The designer's cognizance of the ecosystemic impact of AI-infused objects is imperative, as it enables him or her to discern potential areas for enhancement and implement them. Despite living and working in a multifaceted sociopolitical system, responsibility for sustainable decision-making in companies is not solely ours to bear; however, the designer's role is undeniably well-suited for effecting change in the design of objects towards greater sustainability. This is due to the creative capacity to convert internal and external design limitations into efficacious solutions and more sustainable product service ecosystems.

References

Abramovici, M. (2014). Smart products. CIRP Encyclopedia of Production Engineering, 1-5.

Agrò, L. (2018). IoT designer: Progettare oggetti e servizi relazionali. FrancoAngeli.

Benoît Norris, C., Traverzo, M., Neugebauer, S., Ekener, E., Schaubroeck, T., & Russo Garrido, S. (2020). Guidelines for Social Life Cycle Assessment of Products and Organizations 2020.

Bezzi C (2007) What is evaluation? An introduction to concepts, keywords and problems methodological issues. Franco Angeli, Milano

Brundtland, G. H., & Khalid, M. (1987). Our common future. Oxford University Press, Oxford, GB.

Cook, G., Lee, J., Tsai, T., Kong, A., Deans, J., Johnson, B., & Jardim, E. 2017. Clicking clean: who is winning the race to build a green internet. Greenpeace Inc., Washington, DC, 5.

Coroamă, V. C., Bergmark, P., Höjer, M., & Malmodin, J. (2020, June). A methodology for assessing the environmental effects induced by ict services: Part i: Single services. In Proceedings of the 7th International Conference on ICT for Sustainability (pp. 36-45).

Crawford, K., & Joler, V. (2018). Anatomy of an AI System.

Crawford, K. (2021). The atlas of AI: Power, politics, and the planetary costs of artificial intelligence. Yale University Press.

D'Emidio, T., Dorton, D., Duncan, E.: Service innovation in a digital world. McKinsey Q., 1–8 (2015)

Donald Norman. 1988. The design of everyday things Currency Doubleday. New York.

Donald Norman, and Roberto Verganti. 2014. Incremental and radical innovation: Design research vs. technology and meaning change. Design issues, 30(1), pp.78-96.

Ekvall, T. (2019). Attributional and consequential life cycle assessment. In Sustainability Assessment at the 21st century. IntechOpen.

Foglieni, F., Villari, B., & Maffei, S. (2017). Designing better services: a strategic approach from design to evaluation. Springer.

Gothelf, Jeff, and Josh Seiden. 2021. Lean UX. O'Reilly Media, Inc Greengard, S. (2015). The internet of things. MIT press.

Gupta, U., Kim, Y. G., Lee, S., Tse, J., Lee, H. H. S., Wei, G. Y., ... & Wu, C. J. (2022). Chasing carbon: The elusive environmental footprint of computing. IEEE Micro, 42(4), 37-47.

Holmlid, S. (2010) The design value of business. In proceedings from Service Design and Innovation conference, ServDes.2010. Linköping, Sweden, 1-3 December 2010.

Ilgin, M. A., & Gupta, S. M. (2010). Environmentally conscious manufacturing and product recovery (ECMPRO): A review of the state of the art. Journal of environmental management, 91(3), 563-591.

International Organization for Standardization. (2006). Environmental management: life cycle assessment; Principles and Framework. ISO.

Kim, H., Cluzel, F., Leroy, Y., Yannou, B., & Yannou-Le Bris, G. (2020). Research perspectives in ecodesign. Design Science, 6.

Kloepffer, W. (2008). Life cycle sustainability assessment of products. The International Journal of Life Cycle Assessment, 13(2), 89-95.

Kaack, L. H., Donti, P. L., Strubell, E., Kamiya, G., Creutzig, F., & Rolnick, D. (2022). Aligning artificial intelligence with climate change mitigation. Nature Climate Change, 1-10.

Lacoste, A., Luccioni, A., Schmidt, V., & Dandres, T. (2019). Quantifying the carbon emissions of machine learning. arXiv preprint arXiv:1910.09700.

Larsen, V. G., Tollin, N., Sattrup, P. A., Birkved, M., & Holmboe, T. (2022). What are the challenges in assessing circular economy for the built environment? A literature review on integrating LCA, LCC and S-LCA in life cycle sustainability assessment, LCSA. Journal of Building Engineering, 50, 104203.

Ligozat, A. L., Lefèvre, J., Bugeau, A., & Combaz, J. (2022). Unraveling the Hidden Environmental Impacts of AI Solutions for Environment Life Cycle Assessment of AI Solutions. Sustainability, 14(9), 5172.

Liu, S., & Qian, S. (2019). Towards sustainability oriented decision making: Model development and its validation via a comparative case study on building construction methods. Sustainable development, 27(5), 860-872.

Meyer, G. G., Främling, K., & Holmström, J. (2009). Intelligent products: A survey. Computers in industry, 60(3), 137-148.

Meyer, Michael W., and Don Norman. 2020. Changing design education for the 21st century. She Ji: The Journal of Design, Economics, and Innovation 6.1 (2020): 13-49.

Marc, Hassenzahl and Michael Burmester, and Franz Koller. 2021. User Experience Is All There Is-Twenty Years of Designing Positive Experiences and Meaningful Technology. i-com: Vol. 20, No. 3.

Midden, Cees JH, Florian G. Kaiser, and L. Teddy McCalley. 2007. Technology's four roles in understanding individuals' conservation of natural resources. Journal of Social Issues 63.1 (2007): 155-174.

Nicholad Jitkoff. 2016. Design Is Never Done. Google Design. Retrieved from https://design.google/library/design-never-done/

Peña, C., Civit, B., Gallego-Schmid, A., Druckman, A., Pires, A. C., Weidema, B., ... & Motta, W. (2021). Using life cycle assessment to achieve a circular economy. The International Journal of Life Cycle Assessment, 26(2), 215-220.

Shehabi, A. (2017). Data Clouds and the Environment. In Routledge Handbook of Sustainable Design (pp. 170-178). Routledge.

Souza, A., Watanabe, M. D., Cavalett, O., Cunha, M., Ugaya, C. M., & Bonomi, A. (2021). A novel social life cycle assessment method for determining workers' human development: a case study of the sugarcane biorefineries in Brazil. The International Journal of Life Cycle Assessment, 26(10), 2072-2084.

Spallazzo, D., & Sciannamè, M. (2022). Embedding Intelligence. Designerly reflections on AI-infused products.

Toivonen, M., Saari, E.: Human-Centered Digitalization and Services. Springer, Singapore (2019)

Tokede, O., & Traverso, M. (2020). Implementing the guidelines for social life cycle assessment: past, present, and future. The International Journal of Life Cycle Assessment, 25(10), 1910-1929.

Vezzoli, C., & Sciama, D. (2006). Life Cycle Design: from general methods to product type specific guidelines and checklists: a method adopted to develop a set of guidelines/checklist handbook for the eco-efficient design of NECTA vending machines. Journal of Cleaner Production, 14(15-16), 1319-1325.

Vezzoli, C., Kohtala, C., Srinivasan, A., Diehl, J. C., Fusakul, S. M., Xin, L., & Sateesh, D. (2017). Product-service system design for sustainability. In Product-Service System Design for Sustainability (pp. 49-86). Routledge.

Vitali, I. (2021). A conversation on Conversational Smart Products: how the diffusion of Conversational Interfaces impacts Products and the Design Practice.

Vitali, I., Paracolli, A., & Arquilla, V. (2022). 4. The role of design in the era of conversational interfaces. EMBEDDING INTELLIGENCE.

Wohlschlager, D., Neitz-Regett, A., & Lanzinger, B. (2021, August). Environmental Assessment of Digital Infrastructure in Decentralized Smart Grids. In 2021 IEEE 9th International Conference on Smart Energy Grid Engineering (SEGE) (pp. 13-18). IEEE.

Wu, C. J., Raghavendra, R., Gupta, U., Acun, B., Ardalani, N., Maeng, K., ... & Hazelwood, K. (2022). Sustainable ai: Environmental implications, challenges and opportunities. Proceedings of Machine Learning and Systems, 4, 795-813.