Value misalignments in interactions: an opportunity for sustainable HCI

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Le désalignement de valeurs dans les interactions : une opportunité pour l'IHM soutenable

Value misalignments in interactions: an opportunity for sustainable HCI

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The attempt to link digital and ecological transitions is becoming increasingly present in scientific papers. Since the early 2000s, several new fields of research have developed, covering a very broad spectrum of domains, ranging from environmental computing to the sustainability of human-machine interactions. The diversity of research in these domains has allowed to explore different ways of understanding computing in relation to the ecological transition: at the technical level, at the interaction level, at the impact on social structures, and so on. This article aims at describing to what extent Sustainable HCI (SHCI) needs to deal with alignments between HCI and stakeholders' values in the sustainable transition of socio-technical systems.

CCS CONCEPTS • Human-centered computing → Human computer interaction (HCI) → HCI design and evaluation methods

Additional Keywords and Phrases: SHCI, Strong sustainability, Culture, Values, Sustainable Human Computer Interaction

La tentative de lier les transitions numériques et écologiques est de plus en plus présente dans les articles scientifiques. Depuis le début des années 2000, plusieurs nouveaux champs de recherche se sont développés, couvrant un très large spectre de domaines, allant de l'informatique environnementale à la soutenabilité des interactions humain-machine. La diversité des recherches dans ces domaines a permis d'explorer différentes manières de comprendre l'informatique en relation avec la transition écologique : au niveau technique, au niveau des interactions, au niveau de l'impact sur les structures sociales, etc. Cet article vise à décrire dans quelle mesure l'interaction humain-machine soutenable (IHMS) doit traiter des alignements entre l'informatique et les valeurs des parties prenantes dans la transition soutenable des systèmes socio-techniques.

Mots-clés additionnels : Soutenabilité forte, Culture, Valeurs, Interaction Humain-Machine soutenable

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1 INTRODUCTION

Sustainable human-computer interaction (SHCI) has been discussed in the scientific literature since 2007, when it was introduced at the CHI conference. Blevis first introduced the role of sustainability in the design of interactive technologies, with sustainability being considered as a broad concept. This attempt led to the definition of sustainable interaction design, which was later called SHCI [3]. Blevis' demands are still valid, and the questions he raised remain open: how can we measure sustainability in HCI? What is the link between information technology and (un)sustainable behaviors? Who is responsible for ensuring that the design of technologies is geared towards sustainability? After Blevis, the community started to structure itself. Carl DiSalvo, in 2010, conducted a comprehensive literature review on SHCI and listed 5 main themes that addressed sustainability issues: persuasive technology, ambient awareness, sustainable interaction design, formative user studies, and pervasive and participatory sensing [10]. Starting from those 5 themes, further analysis has been conducted and some of the themes have been recognized as being too narrow in their approach to sustainability. This is the case of works related to persuasion, which accounts for half of the studies in Carl DiSalvo's study [5]. The authors of this paper, in line with other authors in the HCI domain, have a critical approach towards the ability of persuasive techniques to bring about a sustainable transition of socio-technical systems. Indeed, Dourish [12], Strengers [45], [44], and Brynjarsdottir et al. [5] have shown that the work on persuasive technologies is based on liberal assumptions such as the fact that actors are calculating economic agents, maximizing their well-being (notion of utility). Brynjarsdottir et al. carry an even more global analysis where persuasive technologies are positioned in a *modern* perspective, i.e. supported by four major hypotheses: (1) human activities are framed by measurable values, (2) agents' actions are predictable, (3) agents seek efficiency in their actions, (4) control by technology is used to know situations. In our work, we don't support those 4 hypotheses.

We assert that sustainable computing is not *necessarily* about persuasive sustainability. We argue that pervasive computing should be considered as "business as usual", i.e., interactive systems are still contributing to environmental and social damages. We also believe that sustainability needs to be approached as a wicked problem. A wicked problem is characterized by "lack of clarity, uncertainty, ambiguity, high risk, and limited understanding" [35]. Similarly, technology is not seen as an end in itself [37]. Furthermore, it is now accepted that sustainability is considered as a paradigm shift and not an application area. Finally, SHCI needs to be less individual and user-centred but rather extend to groups and even nations [11] to enable systems change. The notion of the anthropocentrism of design in human-computer interaction has been widely examined by Thomas et al [46], leading to the introduction of indirect stakeholders and non-humans in the design of interactive technologies [48]. All these elements have contributed to deepen the understanding of the role of HCI for sustainability [4]. All of this literature allowed Bremer et al. to ask the SHCI community: have we done too much? By wanting to position ourselves in a multidisciplinary way, by using contested concepts, by accepting the complexity of the problems with a reluctance to simplify them, by wanting to change the system and be activist researchers, by considering issues of meso and macro, economic, social scales, have we gone outside the field of human-machine interactions? This article can be considered as an element of response to these questions, since we will show to what extent certain interactive systems are not compatible with the challenges of sustainable transition.

In particular, this article will show that SHCI needs to deal with alignments between values carried by interaction technologies and users in strong sustainability contexts. We will show that if a coherence is not respected between the values of the technical system and the values of a sustainable transition, digital tools have little added value and impact in a logic of transition towards sustainability. An example based on Life Cycle Assessment (LCA) software will be given. Thus, this article is a call to action to better identify the misalignments between values and interaction technologies.

This article is structured in four parts. The first part explains how humanity has entered the Anthropocene era and what we mean by sustainability and ecological transition. This section helps to frame our definition of sustainability and our position which is close to a strong sustainability perspective. The second part discusses the impacts of interactive technologies on society, at different levels. This discussion will help to show that HCI is relevant to tackle values-related issues, especially by addressing structural impacts. In the third part, we argue that values embedded in HCI need to be in line with values related to sustainability. Through the example of Life Cycle Assessment software, we will show that a misalignment between artefacts and stakeholders leads to failures in the sustainable transition of socio-technical systems. Finally, the fourth part aims at positioning our proposal in discussion on the scope of SHCI and we suggest some actions to be launched in the community.

2 CONTEXT: THE ANTHROPOCENE AND THE CONCEPT OF SUSTAINABILITY

This section details our position on sustainability by presenting the current ecological situation and deriving a definition of sustainability. Therefore, the first sub-section is dedicated to the presentation of the concept of the Anthropocene and a brief description of the disruptions of the Earth system, while the second sub-section will be dedicated to the definition of sustainability.

2.1 The Anthropocene: an inhabitable future

Since the industrial revolution, human societies have become a geological force, capable of putting at risk the habitability of planet Earth. Since the beginning of the 20th century, the Earth system sciences have been developing a holistic vision of the functioning of the Earth system. The work of Verdnasky and others has shown that the various elements of the Earth system (physical, biological, chemical, and living elements) are intertwined [41].

The increasing impact of human societies on ecosystems (resource depletion, biodiversity loss, land occupation, land transformation, etc.) have been described in the scientific literature. Even, Rockström and Steffen have developed a model showing 9 planetary limits that mankind must not cross if we want to ensure the habitability of planet Earth [33], [40], [49]. However, 6 of these limits have already been crossed and are beyond the defined risk threshold. For this reason, some scientists have coined the term Anthropocene to designate the new geological period we are in [8, 39]. Although this new geological period is not officially recognised by the scientific community, the emergence of this term highlights the major role of human societies in recent changes to the Earth system. What is sure for scientists is that the Earth System has been drastically changed and that some parts of the world won't be habitable anymore because of a cumulative phenomenon: too high temperatures and too high humidity rate. Also, even if the 9 planetary boundaries are explained separately in some papers, they are interlinked, with for instance climate change and land use impacting biodiversity. In this article we want to investigate what the implications of this new unstable situation are for computing systems and specifically for human-computer interactions. In the next part of this section, we are moving from the concept of Anthropocene to our framing of the concept sustainability.

2.2 Sustainability as a contested concept

In this section, we will talk about sustainability and ecological transition. We will define each concept and the link between them.

Sustainability is a contested concept, and its understanding can differ from one field of research to another. Sustainability has been for example framed by economists with the notion of wellbeing and capitals. In this frame 4 types of capital have been defined: produced, natural, human, and social [9]. In a weak sustainability perspective, those capitals are substitutable. If natural capital is destroyed, it can be replaced by produced or human capital. On the contrary, strong sustainability is a perspective in which none of the capital can be substituted. Our stance on sustainability is closer to a strong than a weak sustainability perspective. Sustainability can be considered as a final state resulting from a transition from an unsustainable state to a sustainable one. A sustainable state would be a society in which human activities do not exceed the planetary boundaries presented in the previous section. The transition towards a sustainable state can be called an *ecological transition*. We define the ecological transition as the transforming dynamic that enables a society to live well within planetary limits [29]. Thus, we define ecological transition as the possibility to transform our ways of being to reach a strong sustainability way of living.

The ecological transition shouldn't therefore be considered as a simple decrease of environmental impacts of human activities. The perspective of ecological transition is oriented towards a structuring change of society. Ecological transition is thus seen as a path towards other ways of living on Earth, consistent with planetary limits. The ecological transition is a radical shift in the way we live. To us, the ecological transition is an epistemological change which will impact the way we design artifacts, and the way we interact with artifacts, especially digital ones. For this reason, we believe that the values embedded in technical systems and in interactions need to be considered and adapted to sustainable contexts. To justify our statement, we need to explain to what extent interactive technologies are currently contributing to the Anthropocene. For this reason, the next section discusses the impacts interactive technologies have on society at different levels.

3 HOW COMPUTER SCIENCE CONTRIBUTES TO INHABITABILITY

The goal of this section is to show that analysing the structural and cultural impacts of interactive technologies, can be important when designing sustainable human-computer interactions. To do so, we will first present the different fields related to sustainability and computing, and then show that HCI has to study sustainability beyond optimization issues.

3.1 Different fields relating sustainability and computing

As of today, there are many different research fields investigating the relationship between computing and sustainability, with different stances on sustainability. In [17], Hilty and Aebisher mapped research fields at the interface of interactive technologies and sustainability and derived 5 main domains with the respective goals in terms of research:

- *Environmental informatics*, whose goal is to understand how computing and modeling can be a support to sustainability;
- *Computational sustainability*, whose goal is to understand the role of interactive technologies in decision making, especially in contexts of conflicting goals;
- *Sustainable HCI*, whose goal is to understand how the interaction between humans and technologies can foster sustainability (impacting behavior, values);
- *Green IT / ICT*, whose goal is to understand how the environmental impact of interactive technologies can be decreased (software and hardware);
- *ICT for sustainability*, whose goal is to understand the contribution of ICT to sustainability, with a focus on systems such as politics, industries and consumers.

We want to add to their analysis another research field "*Collapse informatics*", whose goal is to understand how to design and develop sociotechnical systems in the abundant present for use in a future of scarcity [47].

In every one of these fields, sustainability can be understood in different ways, from weak to strong sustainability. We can take as an example Sustainable HCI (SHCI) and the use of sensors for agriculture. Streed et al. [43] show that precision farming, although it attempts to reduce the environmental impact of the agricultural sector, does not ensure a real sustainability of this sector. The reason behind this statement is that precision farming is a practice that tends to reduce the use of pesticides in monoculture practice. Thus, it doesn't question the practice of monoculture in itself, which is unsustainable. Precision farming can be therefore considered as a weak sustainability perspective as it tends to replace natural capital with technology. Instead, computational agroecology starts from a practice which is sustainable in itself: agroecology. Agroecology is an agriculture practice which is in line with planetary boundaries as it respects the limits of nature. Agroecology is about designing food production systems while respecting nature (conservation practice, and giving back surplus, for instance). However, agroecology is facing difficulties to scale, monoculture remaining the main agricultural system in the world. Raghavan et al. have identified that interactive technologies, as vectors of information and knowledge, can be a means to accompany the deployment of agroecology on a large scale. Therefore, computational agroecology is a scientific domain which proposes a framework to scale agroecology practices, making thus the practice accessible to a wider range of stakeholders [27].

We can then say that the assessment of sustainable interactive technologies is not only about examining the environmental impact of the technical system, but also about assessing the relevance of the whole system in which the technological elements are integrated. The notion of evaluation and structure of the impacts related to interactive technologies are described in the next section.

3.2 Beyond optimization

Traditionally, in the scientific literature the contribution of interactive technologies to sustainability has been categorized into three dimensions: direct impacts, enabling impacts, and structuring impacts [1, 17]. These impacts, represented in Figure 1, are also called "effects". Direct impacts focus on the technical part of technology, which focuses mainly on the materials used to design the interactive technologies (raw materials, impact of fabrication, waste) and the energy used during the different life cycle stages. Enabling impacts focus on the actions the interactive technology enables (what we can do with them). Structuring impacts (called in the figure "systemic impacts") focus on the changes interactive technologies brings to the users (behaviour and value changes). Enabling impacts and structuring impacts are focused on the use phase of the system (middle of life). In a previous article [14], we showed that this structure hides structural and enabling impacts happening during the beginning of the life cycle (extraction of raw materials for instance) and end of life (e-waste). Therefore, this structure seems focused on the use phase and depoliticizes the subject of the global impacts of interactive technologies. By separating the phases, the framework breaks (or doesn't show) the links between causes and consequences. So, if a negative phenomenon has a cause which is economic or due to social structure, it cannot be clearly identified. In this paper we consider technology as being composed of technical, social, and cultural aspects [24]. Thus, those elements have to be taken into account in the framework evaluating the "level" of sustainability of interactive technologies.

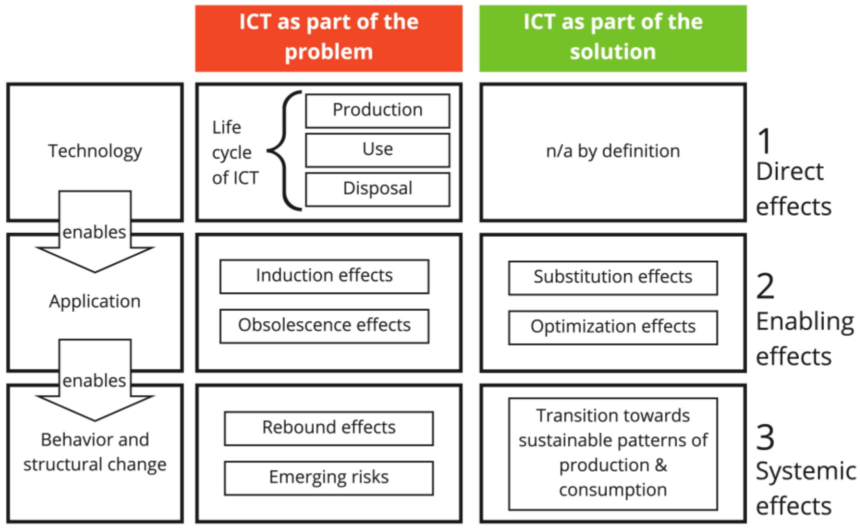

Figure 1: Structure of impacts related to digital systems reproduced from [17]

Moreover, the links between positive and negative impacts are not spelt out. Indeed, optimization in a context of economic growth (apparently positive for sustainability) is leading to rebounds effects (not positive for sustainability). This limit has also been identified by the authors who designed the framework. The potential misalignment between different levels of impacts will be explored in section 4.

Structural impacts depend on socio-cultural and economic contexts. If we go back to the example of agriculture, the culture and structures behind monoculture and agroecology practices are different. By consequence, the usage and role of interactive technologies accompanying the production of food is different. In the agroecology system, interactive technologies are supporting the three "recommendations" defined by Raghavan and Pargman: the respect of ecological limits, the promotion of designs that do not further the cornucopian paradigm[1] and which respect fundamental human needs [28]. We understand these recommendations as structural elements of society because they carry very specific worldviews structuring actions. HCI scientists and designers can define the worldviews, values, and norms embedded in interactive technologies. Thus, we assert that HCI is able to bring some clarifications about the coherence between direct, enabling and structuring impacts.

What is interesting with HCI is that this research field doesn't put interactive technologies as the only cause of environmental issues, or as solution to sustainability problems. The socio-technical perspective of HCI is a major asset to tackle ecological transition through SHCI. Thus, what is interesting with SHCI is that it can be linked to both, technical aspects and cultural aspects of technologies. We are going to see in the next section to what extent this multi-level aspect of HCI is relevant for SHCI, especially for values-related issues.

[1] The Cornucopian paradigm refers to the dominant paradigm of designing interactive systems in a context of infinite resources. Many assumptions support this paradigm, such as the fact that some (home automation) services should be personal (for individuals) and not collective (for families) or that services should be accessible at any time. An elicitation of 10 assumptions of this paradigm is proposed by [26].

4 IMPLICATIONS FOR HUMAN-COMPUTER INTERACTION

This section is about one possible angle to address the contribution of HCI to sustainability: culture and values embedded in interactive technologies. We propose this angle because we believe it is particularly relevant for the future development of SHCI. This section is structured into three parts. Firstly, we will introduce some grounding questions and works related to worldviews and values related to sustainability and carried out by interactive technologies. Secondly, we will show that our discussion takes place in the scope of technocultural approaches. Finally, we will propose the notion of alignment which seems to be crucial to build knowledge around SHCI. We propose thus alignment as a key element to take into account to contribute to SHCI.

4.1 Values in SHCI

Before entering into the why we think HCI could contribute to sustainability, we would like to address some grounding questions. Can we really define values specifically related to sustainability? Should we do that? We know that values are not universal but is it possible to design a global framework for values related to a sustainable way of living?

To answer these questions, we have identified a growing body of work focusing on developing interactive technologies for intentional communities gathered around sustainable goals [15, 20–23]. The works of Nathan et al. use the Value Sensitive Design methodology to identify the values of local communities and to design relevant interactive technologies for sustainable communities [20, 21]. We believe that ethnographic work needs to be conducted more often in order to address the issue of culture and sustainability. In the same vein, other grassroot researches were conducted, for example by Norton et al., to develop local interactive systems in a community [22, 23]. It would be interesting to conduct additional in-depth ethnographic research to explore different sustainable contexts and understand different possible paths for SHCI. In addition, a comparison between the different outputs (of frameworks and values) could be useful to identify some common characteristics among the different case studies. In this paper we decided to not propose a set of values HCI should adopt to become sustainable, but a frame to address this issue starting from "unsustainable" examples.

On the one hand, it remains difficult to identify sustainable worldviews. On the other hand, unsustainable worldviews, values, and actions seem easier to identify as a certain kind of relationship between humans and nature: the worldview that nature can be controlled by humans, humans can manage nature. In addition, the notion of limits has been explored, especially thanks to the research community *Computing within limits* [7, 25]. All those discussions have been developed in the frame of the third wave of HCI, focusing on cultural aspects. This third wave is detailed in the next section while the following section will detail some examples of unsustainable worldviews, values, and actions.

4.2 A discussion anchored in a technocultural approach

In order to be operational, the link between technical features and cultural aspects linked with sustainability embedded in technologies needs indeed to be further studied in HCI. As Sengers et al. explained, "the environmental crisis is as much a cultural problem as a technical one" [36]. In Sengers et al. and the authors of this paper view, culture is understood as a set of attitudes, norms, and values that a person or a group of persons shares. Developing new interactive technologies while not addressing the issue of culture might lead to failures, in particular when addressing strong sustainability contexts of use. Addressing cultural aspects is in line with the third wave of HCI, which focuses more on specific and complex contexts.

Sengers et al., promoted a technocultural approach to SHCI. She defines three elements which are important for this approach. Firstly, she asserts that local contexts are providing meaning to the interaction. Secondly, newly designed systems are considered in their relations with older designed systems (technological debt of the local context). Thirdly, human-machine interaction is not perceived solely as an exchange of information to be optimized, as the stakeholders are understood in their emotional dimension. Finally, ethical questions about the control of the user are raised. All these elements match the features of the third paradigm described by Harrison et al. [16]. The same Harrison coined the term *situated perspective* to define this third paradigm.

We support the idea that the values of the situation in which the interaction takes place have to be in line with the values the interaction supports. Therefore, the match between the context and the interaction, and thus the interactive technology, is crucial. This necessity for alignment between the context, stakeholders and the interaction is discussed more in depth in the next section, and constitutes the core of our proposal.

4.3 The importance of alignment

Our positioning is that interactive technologies must be designed in a way that doesn't bring misalignment between worldviews, values, and competencies for direct and indirect stakeholders. Methods centered on the importance of a match between values embedded by the artefacts and the users' values (i.e., participatory design, value sensitive design, and other approaches) already exist. We argue that the presumed match between values and artifacts is even more relevant for projects concerning interactive technologies created for sustainable contexts. Only in this way we can ensure that the *structuring* impacts of the system (i.e., the ones impacting behaviors and values) are relevant with respect to sustainability. However, this alignment can be difficult to do.

Biberhofer et al., [2] and Sterling et al., [42] have worked on a framework which describes potential links between worldviews, values and actions, passing through competencies. This framework coming from the sustainable development education field is of particular interest because competencies for sustainability are very well defined. Therefore, it can be easy for stakeholders to assess their competencies for sustainability. The framework is represented in Figure 2 and is called the system of nested knowledge. The use of interactive technologies can have impacts on beliefs, norms and ideas of individuals or groups. We assert that use of interactive technologies can also help developing specific competences: systemic thinking, ability to work in an interdisciplinary group, critical thinking, just to name a few. Therefore, competencies can help to define the different values which are supporting sustainability. For the same reason, some features of interactive technologies can hinder the ability of users to develop competencies and act on them.

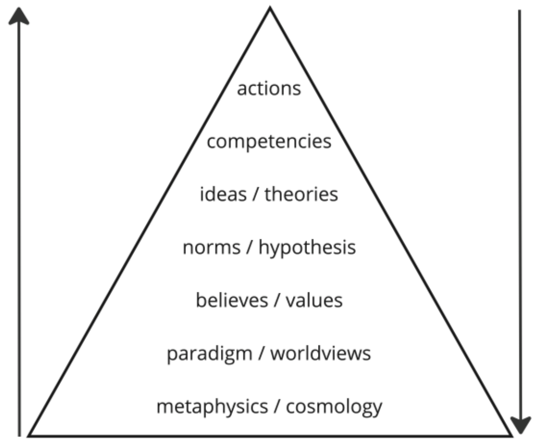

Figure 2: Nested system of knowledge reproduced from [2]

If we summarize the elements listed and discussed in previous sections, we can identify 3 types of misalignments that can hinder the impacts of a system accompanying the ecological transition. These misalignments are represented on Figure 3 and listed here:

1. [VALUES – VALUES] A misalignment between stakeholders' values and the values that some software carries (gap between the stakeholders and the software regarding one type of knowledge of the nested system, for instance values);
2. [VALUES – ACTIONS] A misalignment between the values carried by the stakeholders and the potential actions that the software can provide (gap between different kinds of knowledge of the stakeholders due to the software);
3. [IMPACTS] A misalignment between the different effects of the interactive technology (direct, enabling, systemic effects).

In order to make our reasoning and statements less abstract, in next section we are using the example of the Life Cycle Assessment (LCA) software to demonstrate the risks of these 3 kinds of misalignments.

4.4 A practical example

Life Cycle Assessment is a method for evaluating the environmental impacts of a product or service. The LCA method follows the ISO14000 and ISO14040 standards [13]. The LCA approach is composed of 4 main steps, carried out in an iterative manner: (1) definition of the objectives and scope of the study, (2) life cycle inventory, (3) impact assessment, (4) interpretation of the results. A final step (direct applications) looks at the extent to which the results obtained will impact the real world (the production system, the company's business model, and so on). LCA is supported by calculation tools and databases which are crucial for the impact calculations. LCA software targets mainly experts [32].

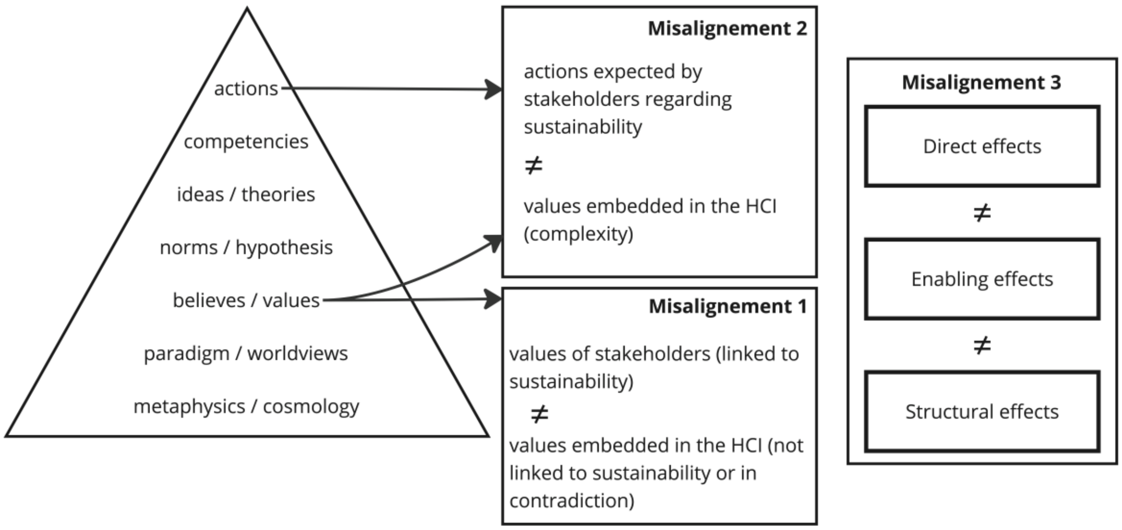

Figure 3: Representation of 3 types of misalignments between HCI and stakeholders regarding sustainability

In the rest of this section, we are going to analyse LCA software and show how this kind of software is a good example of all 3 types of misalignments. The authors of this paper have observed the use of an LCA software during 6 months. The group we observed was composed of 6 inhabitants of an eco-village, non-experts in environmental assessment. This situation was an opportunity to position our observation in a strong sustainability context. In those 6 months with 9 sessions of work, the group we observed succeeded in assessing the environmental impact of a tiny house. The group used an LCA software and an intermediate tool to exchange and discuss. Through this experience we could observe a mismatch between values and practices of the group's members and the values embedded through the possibilities provided by the software. Among the inhabitants, some important values have been identified through motivational interviews. The values identified are the following: (1) autonomy of individuals in their choices, actions, and the representation of themselves, (2) involvement in collective dynamics, (3) transparency in the governance system and the management of data related to inhabitants, (4) the need to act responsibly in a context of ecological urgency. In the rest of this section, we detail the elements that brought us to recognize the 3 types of misalignments in this particular context.

4.4.1 Misalignment 1: between stakeholders' values and the values that some software carries

The democratisation of knowledge of the actions to be taken for a sustainable transition is crucial to extend this transition to the whole of society. There is a tension between this need for democratisation and the complexity of LCA, which prevents stakeholders from taking ownership of the LCA process.

LCA software carries different forms of complexity: complexity in the vocabulary used in the interface, complexity of data to understand, complexity in communicating results to stakeholders, complexity of usage, and so on. This situation is created by different aspects: the functions proposed by the software, the public the software targets, the interface design. This complexity doesn't enable non-experts to carry an LCA. The system doesn't provide the ability for non-experts to understand the concepts and the data. In addition, some expertise is needed to understand a large set of industrial processes (documentation on industrial processes during several weeks) and the environmental indicators

(Inhabitant verbatim: “I don’t know what is eutrophication[2]”). Democratization of knowledge on environmental assessment is difficult if not impossible with LCA. This complexity is contradictory with e.g., the value of autonomy we previously identified for the inhabitants. This discrepancy between the autonomy needed by inhabitants to conduct environmental analysis (to understand their impacts and ensure consistency with global limits) and the complexity of the LCA software is therefore contradictory.

Members of the focus group did not accept that all data was not available. Members of the focus group expressed a need to have data open and meaningful to have some autonomy in the conduct of the LCA and being able to take decisions on results they understand. This requirement was difficult to fulfil with closed and expert systems. Thus, the actors of the ecological transition are confronted with a closed culture of LCA data and software.

4.4.2 Misalignment 2: between the values carried by the stakeholders and the potential actions that the software can provide

The need to act responsibly in a context of ecological urgency has been identified through interviews made with inhabitants. This general need is related to the practical inhabitants’ need to make everyday choices to restore and built the eco-village. This need (and everyday practice) wasn’t in line with the LCA method and thus with the use of the LCA Software. Indeed, the understanding of the technical system wasn’t deep enough from the inhabitants’ side: researcher verbatim: “how do you see the use of LCA within the eco village in terms of organization?” Inhabitant: “I don’t see it because I don’t know how to use the software”. This verbatim from an interview 6 months into the observation shows well the inability for inhabitants to define the potential use of a software that is supposed to help product designers to understand the impacts of what they are going to produce on real world. In this example not only values are misaligned but the ability of stakeholders *to act* for sustainability is impacted. In addition, the data provided in the databases were too complex to be understood by the members of the focus group, leading to a demobilization of the focus group members. Resident vebatim: "OK, you see I would have given up already on my own. Seeing that there is not what I am looking for in the database..." . It is thus possible to see that the mismatch between values and interactions is hindering the adoption of a potentially useful method for sustainability (LCA) because of a too high-level software that does not create a link to everyday actions of the group using it.

4.4.3 Misalignment 3: between the different effects of the interactive technology

We asserted previously in this paper that there is a necessity of alignment of all the three types of impacts: systemic, enabling, and direct impacts. If we take the example of LCA software use, it means that LCA software should have direct, enabling and structural impacts in line with sustainability. What does it mean concretely?

Sakellariou defines the ideology of LCA as the *ideology of technological change*, as LCA is anchored in an engineering practice based on control, and on the belief that technological practices can be improved by experts [34]. This position is problematic in relation to the need for all project stakeholders to understand the environmental impacts generated and to act accordingly. Thus, the values embedded in the software (structural impacts) do not necessarily allow for a democratisation of knowledge related to the environmental aspects of engineering (enabling impacts). Because of these structuring elements of LCA, the enabling impacts are therefore restricted to organisations with the capacity to have an

[2] Eutrophication is a phenomenon by which a body of water (lake, sea, ocean) becomes enriched with minerals and nutrients (phosphorus). The growth of aquatic plant life is stimulated, which leads to a depletion of oxygen availability and the death of living species. Eutrophication is an indicator of environmental impact.

expert (cost, time, accounting of internal practices). The difficulty of using the software may in addition lead the organisation not to use it (direct impacts).

In addition, a Life Cycle Assessment may lead to the redesign of certain products and services to reduce the unit environmental impact of these goods. If this unitary reduction is accompanied by a reduction in the unitary financial cost, there is a risk of increasing the number of goods produced. In this case, the company may be encouraged to produce more and thus there is no strict reduction in the environmental impacts of production. If we want to push our reasoning further, we could even question if the whole LCA method is a real enabler for the ecological transition. As a matter of fact, it's one of the most spread methods addressing the impacts of production, and one of the few using a software.

We have seen that the non-alignment between the values of the tools and the values of the users can call into question the "sustainable" character of an interactive technology. We have also briefly discussed the situated nature of these interactions, especially the adequacy with strong sustainability contexts. However, this element should be better taken into account in following studies, given that each cultural context of strong sustainability may have its own specific values, and therefore will need interactive technologies supporting those values in that specific context.

How can new software convey values other than those linked to capitalism? Current software is mainly not aligned with sustainability values. How can we redesign this software? Should we take into account this "technological debt"? It should also be noted that not all communities or organisations are necessarily aligned with sustainability values. Therefore, tools carrying sustainability values will find themselves out of step with these non-sustainable organisations. An articulation will have to be found between cultural debts (carrying capitalist worldviews for instance) and new sustainable cultures emerging.

The field of HCI has the characteristic of being interdisciplinary and of approaching the issues of interactive technologies in a socio-technical way. This characteristic is a real opportunity to ensure that HCI has a place in the production of knowledge for sustainability sciences and actions.

5 DISCUSSION

The discussion is twofold. The first section positions our paper in the discussion launched by Bremer et al. [4]. The second section suggests some actions which could led to a better understanding of sustainable interaction systems.

5.1 Position regarding the place of values in SHCI

The work by Bremer et al. [4] asks the following questions: as researchers in sustainable HCI, have we done too much? In wanting to integrate the full complexity of sustainability issues, have we taken on too much responsibility for the scope of HCI? Through a critical literature review, Bremer et al. challenge the field of sustainable HCI: too interdisciplinary? Too complex? In relation to the questions posed, we believe that our proposal provides some answers. The question of culture and values is part of the 3rd wave of HCI, which focuses on the cultural and contextual dimensions of interactions. Thus, it does not seem to us that these questions are outside the scope of HCI. Moreover, solid methodologies linked to the expertise at the heart of the HCI community exist (for example, Value Sensitive Design). Finally, the field of HCI makes it possible to create a continuum between reflective and philosophical proposals and the experiments / prototypes implemented to test these proposals.

The field of sustainable HCI aims to challenge the hypothesis that a technology - especially a computerised technology - can solve ecological problems. One of the contributions of the community is to experiment with human-technology interactions in contexts of strong sustainability in order to bring to life a narrative that competes with the

Cornucopian paradigm. It is in this dynamic that we are convinced that our proposal of value alignment is relevant. Indeed, the analysis of values makes it possible to highlight the interactive systems that implicitly or not support values around the Cornucopian paradigm.

It seems necessary to explicit the role of our papier in the design of a competing narrative to the Cornucopian paradigm. By focusing on the mismatches between values hold by stakeholders and values embedded in interactive systems, those values are made explicit. We believe our proposal participates to the discussion about finding metrics for the evaluation of SHCI. This need for metrics is urgent in the community [4, 14, 19, 30, 31] and value analysis is a way to qualitatively assess interactions.. More than metrics, we suggest in the next section some actions that the community could put into practice.

5.2 Plan to action

Thanks to this study, we tend to gather some actions that could be launched within the SHCI community:

- *Database of examples of misalignments* in order to better identify them easier in the near future. We can hypothesize that misalignments are common in our world and that this pool of examples will help practitioners to identify them. Thus, we have created a digital space where people can add records and sort them by type of misalignment, by technical system studied and by sustainability context[3]. We hope this space will enable members of the community to better identify misalignments.
- On the basis of this database, more knowledge on the subject could be collected. *Develop a multi-scale understanding of sustainable HCI,* in order to be able to identify mismatches between 1st, 2nd and 3rd order effect. This thinking is particularly appropriate for computer systems as these systems are multi-scale (taking into account not only the artefact but also the whole digital infrastructure necessary for its operation [24]). In practice, this multi-scale thinking can be disseminated through training programs. We hope that this will enable future designers to take values more into account in the design phase of assets. Such a movement could help SHCI to increase the sustainability of interactive systems, as they will be designed a priori with a sustainability mindset and will be more socio-technically oriented [6].
- *Explore explicitly strong sustainability contexts through long-term studies* to explore narratives that compete with the Cornucopian paradigm. There is a lack of practical examples to bring these alternative narratives to life. In-depth ethnographic research will help to explore different contexts of sustainability and to understand the different possible paths for SHCI. Similarly, studying sustainability contexts could help to identify the appropriate metrics to assess the relevance of an interactive system in these contexts. We therefore need to create spaces for these types of studies, and open internships and PhD theses on these areas of study. We can add that these long-term studies can be carried out in action research frameworks, allowing a faster transfer of knowledge between researchers and communities in transition [18]. This faster transfer is a boon given the current ecological emergency.

6 CONCLUSION

We have seen that the field of SHCI has developed considerably since its birth in 2007. Thanks to literature reviews, we have been able to show that this field of study has grown in depth and complexity. The understanding of sustainability in each field of study however remains heterogeneous. We argued that sustainability needs to be

[3] Link towards the platform: https://github.com/LouGrimal/Misalignments-SHCI

understood in a radical sense in order to ensure that the field of HCI is relevant to the knowledge of sustainability. We also argued that one of the major aspects of strong sustainability is the link with the cultural context and values. Thus, we assert that anchoring more HCI into studies relating culture, values and sustainability could help developing knowledge on SHCI. Only this way SHCI can act as a system to accompany the ecological transition: aligning worldviews, theories, norms and values related to sustainability. We focused on misalignments between different levels of impacts of HCI, and misalignments between interactive technologies' values and stakeholders' values. SHCI could accompany the emerging sustainable cultures to support the existence of sustainable communities: "a culture evolves when new practices, introduced for perhaps irrelevant reasons, are selected by their contributions to the survival of the practicing group" [38]. We can conclude that, by exploring cultural contexts of strong sustainability, the field of HCI has the opportunity to propose interactive technologies aligned with the values and cultures of these contexts.

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