Design Philosophy Papers

ISSN: (Print) 1448-7136 (Online) Journal homepage: http://www.tandfonline.com/loi/rfdp20

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To cite this article: Eli Blevis (2006) Advancing Sustainable Interaction Design: Two Perspectives on Material Effects, Design Philosophy Papers, 4:4, 209-230

To link to this article: http://dx.doi.org/10.2752/144871306X13966268131875

Published online: 29 Apr 2015.

Design Philosophy Papers VOLUME 4, ISSUE 4 PP 209–230 PHOTOCOPYING PERMITTED BY LICENSE ONLY

Advancing Sustainable Interaction Design

Two Perspectives on Material Effects

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Preface

This paper continues, elaborates, and extends parts of one which has been accepted to appear as a long archival paper and presentation at the 2007 Annual Association for Computing Machinery's (ACM) Special Interest Group on Computer-Human Interaction (SIGCHI) Conference on Human Factors in Computing Systems, CHI 2007. The conference paper title is "Sustainable Interaction Design: Invention & Disposal, Renewal & Reuse,"[1] hereafter referenced as *the conference paper* in this text. Among other things, it introduces a rubric of potential material effects of interactive information technologies and several design principles that form part of a perspective of sustainability. In this paper, I greatly expand on the description and illustration of the rubric in particular and distinguish between design criticism and critical design perspectives for both the rubric and the principles.

I state this detail not just as a matter of scholarly disclosure, but also as a portion of a tale of two constituencies, namely the SIGCHI constituency – also know as the Human-Computer Interaction (HCI) or synonymously, the *interaction design* constituency – and the design constituency, which is represented not only by the readership of and contributors to DPP, but also by the constituency that surrounds design issues, design studies, and other design journals, venues, and conferences. I use the term "constituency" in place of "community" deliberately to indicate that perspectives can vary widely within these less-than-communally-cohesive groups. In some sense, the design philosophy constituency can be characterized as one that is primarily concerned with *design criticism*, providing the understandings needed to uncover the effects of present courses of action and inform future ones. On the other hand, the interaction design consistency can be characterized as one that is primarily concerned with *critical design* – by which I mean the actual practice of design with the materials of information technologies critical to the goal of promoting sustainable ways of being which at its best is informed by design criticism and at its worst blindly promotes the unsustainable.

As topical as these differences in perspectives are – particularly in the HCI constituency, the discussion of them is only context for the central point – a vision and foundation for sustainability as a focus of interaction design. Since acting more sustainably with respect to our interactions with, and decisions about, the use of the materials of information technologies is vital to our collective futures, the goal of this work is to find ways to bridge these differences in perspectives, setting nuanced thinking about sustainable design from the perspective of *design criticism* in operationalizable terms of *critical design* for interaction designers and providing impetus for positive change.

The paper is organized as follows:

(a) In "Setting Sustainability as a Focus of Interaction Design," I describe the need to set sustainability as a central focus of interaction design from the twin perspectives of design criticism and critical design;
(b) In "A Rubric of Material Effects," I present a description and illustration of a rubric which may be used to understand the possible material effects of design with the materials of information technologies;
(c) In "Five Principles of Sustainable Interaction Design," I sketch five principles to guide interaction designers from the perspectives of design criticism and critical design and relate the principles to the elements of the rubric;
(d) In "Future Directions," I close with a brief summary and a description of expectations for the future.

Setting Sustainability as a Focus of Interaction Design

In the conference paper, I make the following claim:

> I claim that sustainability can and should be a central focus of interaction design – a perspective that I call Sustainable

> Interaction Design (SID). I propose several aspects of a framing for a research program and methodology germane to this way of thinking about interaction design – a way of thinking that is critical for our collective futures. The vision – design – for this future concerns defining sustainability as a core semantics for interaction design. As a starting point for a perspective of sustainability, I define design as an act of choosing among or informing choices of future ways of being, a definition which is inspired by several important design authors – principally by Tony Fry's notion of defuturing in his book 'A New Design Philosophy: An Introduction to Defuturing'[2] and as well by Willis' notion of ontological designing,[3] which itself owes to Winograd & Flores' "Understanding Computers and Cognition: A New Foundation for Design"[4] as well as to Heidegger's essay 'The Question concerning technology.'[5] Alexander's recent work on structure-preserving transformations is also an inspiration.[6] This definition of design from the perspective of sustainability serves as a lens through which design values, design methods, and designs themselves may be evaluated, especially in the context of interaction design.

The perspective of sustainability as defined above reflects the potential for forward-looking action and for designing as an agency of change towards viable futures – a phrase which owes to Fry.[7] The contra-positive must also be considered – that is the question of how does the present course of action predict ways of being that yield unsustainable futures? – another phrase which owes to Fry.[8] This latter perspective is the dominion of design criticism, as a complement to design practice and as interpretations of politics, culture, fashion, economics, enterprise, science, technologies and so on. Acts of choosing among or informing choices of future ways of being need to be informed by acts of understanding the impacts and potentials of our present ways of being. We may distinguish here between *design criticism* – what is needed to understand and interpret present ways of being, and *critical design* – what is needed to ensure that our actions lead to sustainable future ways of being.

Time being what it is, critical design takes place in the absence of complete understandings of present ways of being. Thus, design criticism and critical design are mutually dependent, ongoing, and co-evolving acts. Design without design criticism is unlikely to create *critical design* and criticism without critical design is unlikely to create *design criticism*. Design criticism is strategic. Critical design is tactical.

This distinction between critical design and design criticism suggests an essential first refinement for a definition of the perspective of sustainability that can be presented in two parts,

(i) a *design criticism perspective of sustainability* in which *design* is defined as *acts of understanding the potential effects of present ways of being on future ways of being* and (ii) a *critical design perspective of sustainability* in which *design* is defined as *acts of choosing among or informing choices of future ways of being.* Furthermore, the emphasis in this definition on acts of understanding, choosing, and informing choices applies not only to a notion of sustainability that engages environmental issues, but also to one which engages issues of politics, culture, fashion, enterprise, science, technologies, and so on.

A Rubric of Material Effects

In addition to proposing this perspective of sustainability and identifying its twin forms of design criticism and critical design, I propose in the conference paper, and here greatly elaborate and illustrate a rubric for understanding and assessing the material effects induced by particular interaction design cases in terms of forms of use, reuse and disposal from the perspective of sustainability. As I state in the conference paper,

> The items of the rubric are disposal, salvage, recycling, remanufacturing for reuse, reuse as is, achieving longevity of use, sharing for maximal use, achieving heirloom status, finding wholesome alternatives to use, and active repair of misuse. The important claim is that software and hardware are presently intimately connected to a cycle of mutual obsolescence with implications for the environmental and sustainability effects and modes of use enumerated by the rubric.

From the perspective of sustainability with respect to interaction design, the rubric can be used as a frame for design criticism as well as metrics with which to assess concepts of critical design.

In what follows, I give some examples, but caution that any particular example can not be construed as representative of the entire scope of the problem of establishing the connections between the effects named by the rubric and the use of the materials of information technologies. Some of the examples look broadly to *design criticism* inspired alternatives to existing infrastructures which promote the unsustainable and some of the examples look narrowly to *critical design* inspired alternatives for working within existing infrastructures in more sustainable ways. It is my hope that this paper will be valuable to the two constituencies I describe in the preface, and therefore the examples are essential for understanding and bridging understandings.

1. **the material effect of disposal** – does the design cause the disposal of physical material, directly or indirectly

and even if the primary material of the design is digital material?

From the perspective of design criticism, the extent and environmental cost of disposal of materials in the making, use and retirement of systems should be considered as part of the critique of a system. Similarly, the actual motivations for systems that use the materials of information technologies in the context of human behaviors and global conditions need to be examined – what are the behaviors of particular systems which lead to disposal support and are there alternative means of support or alternative behaviors or organizations of society that would minimize or remove the need for the use of systems requiring disposal? How can such alternatives be motivated so that people actually prefer them?

From the perspective of critical design, the challenge is to uncover ways to minimize the disposal of physical materials that may be caused by the use of digital ones. On another level, the challenge is to devise courses of action that make people aware of the connection between the use and adoption of digital materials and the potential for disposal of physical ones, providing alternatives.

As an example of how digital material can cause the disposal of physical material, consider the implications of the introduction of Microsoft's new operating system, Vista, in 2007. The effects have implications for both *consumers* and enterprise. Writing in the trade magazine *Information Week* and quoting the marketing intelligence firm IDC, Gregg Keizer wrote on 11.29.06 that

> Adding its voice to the chorus forecasting Windows Vista uptake during 2007, IDC said Wednesday that it expects the new operating system to grab a beachhead of 90 million PCs next year, largely on the back of new computer sales to consumers.[9]

Also writing in *Information Week,* Sharon Gaudin reports on 12.06.06 that

> About half of business PCs are unable to run Microsoft's Windows Vista operating system because they don't have the basic system requirements, according to a new study.
>
> A study of 112,113 desktops at 472 North American companies shows that, in general, any computer two years old or older probably won't be able to support Vista, according to Dean Williams, a services consultant for Softchoice, the technology and services provider that conducted the study. …
>
> When it comes to computers that are able to meet Microsoft's "premium" vista requirements, 94% don't measure up.[10]

It is important to keep in mind that these are only predictions and that other software companies are equal participants in the release of new software that causes disposal and other material effects of hardware. In some cases, Vista hardware upgrades may involve replacing only components of existing machines. In others, such as with laptop computers, consumers and businesses may replace equipment to accommodate the demands of the new operating system. Some of the obsoleted equipment and components may be disposed and some may be salvaged, recycled, or be the cause of other material effects.

The need for new machines to run a new operating system is in large part *designed* by the requirement for a larger footprint – a technical term for the amount of resources needed by a program – than existing machines currently can provide. Moreover, computer "users" who fail to upgrade to the new operating system risk being stranded with existing software applications which cannot be maintained as the present operating system becomes unsupported, as well as systems that become hopelessly insecure over time.

Many alternative Linux-based operating systems from the open source world are actually engineered to use small footprints in order to make use of existing machines. One example of such a Linux-based system – introduced to me by Peter Scupelli, a doctoral student in HCI at CMU – is Ubuntu and its variant Xubuntu which is specifically designed to endow older less powerful machines with a modern operating system.[11] The barriers to widespread adoption of *eco-friendly* Linux-based software are many and complex, including the inertia of the existing infrastructure of expertise and culture of Windows-based machines in enterprise, and the familiarity of Windows-based software in the "consumer" market. The Mac OS market share is presently a significant 5%, but not enough to change the balance and it is not at all clear that Apple's strategic design is different in environmental terms than Microsoft's. Linux-based systems have a strong foothold in enterprise, but arguably require highly specialized and savvy administrators, making them less practical for *consumer* use.

2. **the material effect of salvage** – does the design enable the recovery of previously discarded physical material, directly or indirectly and even if the primary material of the design is digital material?

From the perspective of design criticism, the means and possibilities for salvage of obsoleted and otherwise retired physical materials associated with systems that embed the materials of information technologies should be considered to be part of the design and critique of such systems as they are first construed. One needs to ask such questions as how the salvage is done, by whom, what are the exposures to toxins in the environments in which the salvage takes place, who bears the cost of salvage, and how much is disposed of which otherwise might have been salvaged? Similarly, alternatives to systems which require salvage must be imagined.

From the perspective of critical design, the challenge is to uncover ways (i) to minimize the need for salvage due to premature retirement of physical materials prompted by the use of digital ones, and (ii) to maximize the salvage of what may have otherwise been disposed, subject to ensuring the safety and well-being of those employed to actually do the salvaging.

As an example of how digital material can cause the salvage of physical material, consider what happens to the computers discarded by industrialized societies. In the conference paper, I quote from Charles Schmidt[12] writing in *Environmental Health Perspectives*. Here, I quote more extensively:

> Hungry for information technology but with a limited capacity to manufacture it, Africa has become the world's latest destination for obsolete electronic equipment. Much of this material is more or less functional and provided in good faith by well-meaning donors. But the brokers who arrange these exports often pad shipping containers with useless junk, essentially saddling African importers with electronic garbage. In 2002, the Basel Action Network (BAN), a Seattle-based environmental group, made headlines with its investigation of e-waste exports to Asia [see "e-Junk Explosion," EHP 110:A188–A194 (2002)]. More recently, BAN explored Africa's e-waste problem, and described its findings in an October 2005 report titled '*The Digital Dump: Exporting Re-use and Abuse to Africa'*.
>
> …
>
> An estimated 500 shipping containers loaded with secondhand electronic equipment pass through Lagos each month, BAN's investigation found. Each container can be packed, on average, with a load equal in volume to 800 computer monitors or central processing units (CPUs), or 350 large TV sets. Local experts cited by BAN estimate that anywhere from 25% to 75% of this material is useless. Assuming the low end of this range, one could hypothesize that volumes of e-waste equal to 100,000 computers or CPUs, or 44,000 TV sets, enter Africa each month through Lagos alone.
>
> …
>
> Asia does, in fact, have a thriving electronics recovery industry that supplies manufacturers with recycled raw materials. While the practice does have its benefits, as noted above, it also exploits women and child laborers who cook circuit boards, burn cables, and submerge equipment in toxic acids to extract precious metals such as copper. BAN documented these practices, which have dire health and

> ecological consequences, during its 2002 and 2004 visits to China. However, BAN investigators didn't witness this type of activity in Nigeria. Puckett speculates this might be because waste volumes there aren't yet high enough to realize profits from recovery. In that case, he suggests, it could be just a matter of time before the same hazardous e-waste extraction methods observed in China emerge in the Lagos street economy.

In Schmidt's article there is a photograph of a young man disassembling discarded computers in the hopes of salvaging parts to make complete, operating ones. Some of the unusable parts are burned, creating extremely toxic conditions for those engaged in this industry. One of the biggest toxins is lead from discarded CRTs. I report as well in the conference paper that Townsend et al.[13] provide scientific detail on the toxic nature of discarded computer electronics. A great deal more details and specific current quantification of the problem are given in Alastair Iles' paper, *Mapping Environmental Justice in Technology Flows: Computer Waste Impacts in Asia*.[14] Iles also identifies the poor conditions that affect those employed in the recycling of old computers (p.83):

> most e-waste analyses do not acknowledge the settings that shape how recycling takes place. E-waste imports may gravitate most to those places where pre-existing institutional and political conditions intersect with social and economic developments to create vulnerable populations.

3. **the material effect of recycling** – does the design make use of recycled physical materials or provide for the future recycling of physical materials, directly or indirectly and even if the primary material of the design is digital material?

From the perspective of design criticism, the opportunities for recycling of obsolete and otherwise retired physical materials associated with systems that embed the materials of information technologies should be considered to be part of the design and critique of such systems as they are first construed. Recycling seems to be preferable as a material effect to salvage and disposal, but this is only true when the environmental costs of recycling are less than the environmental costs of salvage and disposal and in the absence of alternatives for reuse. The question of when and how recycling of computers can actually have an environmental benefit is a complex one that is the topic of a recent edited volume by Kuehr & Williams.[15] The public policy issues in the United States are described in a congressional report by McCarthy,[16] and compared to policies in other countries.

From the perspective of critical design, the challenge is to uncover ways to design interactive software that reduces requirements for recycling, salvage, or disposal. The roles of interaction designers in the material effects of recycling is less well documented than the roles of engineers, computer product manufacturers and public policy makers. For example, designing software that requires higher screen resolutions can lead to material effects of recycling, salvage, and disposal. Designing software that adapts gracefully to different screen resolutions may possibly minimize these effects. On the other hand, interaction design that makes it easier to read and access materials online at the expense of creating a need for greater screen resolutions may eliminate the need for material effects of printing – to date, studies in HCI have indicated that people far prefer to read on paper than on a screen, but I have personally stopped printing almost entirely since I purchased a 1200 × 1600 resolution capable monitor with portrait mode software that allows me to view a full page of text at larger than life resolution. I do not here compute how much less use of paper is needed to offset the environmental impact of the production of this portrait-mode software capable monitor, its energy use, and the consequent potential for early retirement of the monitor it replaces. The links between interaction design and material effects of recycling involve a complex mix of factors. In this paper, I am not claiming to be able to account for the specific trade-offs that these links imply, only that interaction designers must take them into account and that this rubric is part of a suitable foundation for the analysis.

Some “green” programs on consumer product company web-sites focus on recycling as a mechanism to ease the conscience of consumers who want to buy newer equipment. In the conference paper, I report that:

> The Hewlett Packard (HP) company[17] has a program that allows consumers and businesses to trade-in old equipment, even equipment that was not manufactured by HP. The depreciated trade-in allowance for the one year old HP laptop on which I am writing this article is only 20% of the original value according to the companies’ web-site. The company accepts any old equipment for recycling – non HP equipment is accepted at the consumer’s expense. It costs $9.00 US plus shipping to recycle a laptop computer. The company claims to handle 3 million pounds of equipment per month, claiming to reduce such equipment to raw materials for the manufacture of new equipment. Apple Computer[18] has a similar program, as does Dell.[19]

If my claim above seems harsh – that recycling may be targeted by US manufacturers more as a mechanism to ease the conscience of consumers who want to buy newer equipment than as a viable approach to sustainability – consider the following analysis, again from Iles (p.87):

> the populations, governments, and corporations who benefit the most from computer use – in the form of health services, educational systems, provision of social welfare, productivity gains, monitoring of environmental pollutants, efficient transportation networks, and banking services – are largely located in industrial nations. In turn, most computer ownership in developing nations, as in industrial nations, is associated with the middle class and with business and government. Moreover, the corporate and individual actors who directly profit from computers – manufacturers, designers, retailers, and recyclers – in both industrial and developing countries do not keep close tabs on what happens to their technology. They do not pay for health monitoring or preventive care among recycling workers, therefore creating new human externalities hidden in the PCs sold in stores. They do not pay for high standard recycling infrastructure in Asia, nor do they take the effort to determine whether or not environmental and labor standards exist or are being enforced by regulators. In effect, pollution is moving from industrial countries to Asia in both the manufacturing and recycling phases. Recycling only compounds the degradation that manufacturing causes.

4. **the material effect of remanufacturing for reuse** – does the design provide for the renewal of physical material for reuse or updated use, directly or indirectly and even if the primary material of the design is digital material?

From the perspective of design criticism, the opportunities for remanufacturing of obsolete and otherwise retired physical materials associated with systems that embed the materials of information technologies should be considered to be part of the design and critique of such systems as they are first construed. We can say that a device is remanufactured for reuse if only selected parts are repaired, replaced, or upgraded. The lines between remanufacturing, maintenance, and salvage may be hard to draw in some cases. Remanufacturing may be preferable to recycling, salvage or disposal just in the case that the environmental costs of remanufacturing are less. Such costs must take into account many factors including the cost of disposal, salvage, or recycling of any retired components, and the cost of energy needed to run a device compared to newer ones which may employ more energy efficient technologies.

From the perspective of critical design, the challenge is for interaction designers to consider the possibilities for how their designs can promote remanufacturing for reuse over recycling, salvage, and disposal in the case where environmental benefits accrue from so doing. For example, interaction designers (i) could specifically target older computers as platforms for software or ubiquitous interactive devices, or (ii) they could design communications or design enterprises that make it easier for people to upgrade and repair their existing equipment, or (iii) they could provide mechanisms that help people repurpose older equipment for uses which would otherwise have required the purchase of a new device, such as using an older pc as a router, or (iv) they may design software or interactive devices that makes it easy for people to track the path of donated equipment to un-conceal how such equipment is actually used or otherwise retired.

The marketplace viability of remanufacturing is argued and modeled in Ferrer's *The Economics of Personal Computer Remanufacturing.*[20] In the conference paper, I give the following examples:

> The Australian company Cartridge World is a world-wide franchise that seeks to make it easy for people to refill inkjet printer cartridges rather than purchase new ones. The company USA Notebook.Com, Inc. is in the business of remanufacturing laptop computers and making them available for sale over the internet, providing a warranty to its customers.

The major computer manufacturers, HP, Dell, and so forth all have programs that market remanufactured equipment, but conspicuously do not appear to provide programs that allow, encourage, or assist consumers to upgrade existing equipment.

5. **the material effect of reuse as is** – does the design provide for transfer of ownership, directly or indirectly and even if the primary material of the design is digital material?

From the perspective of design criticism, the opportunities for reuse "as is" of systems that embed the materials of information technologies without the need for remanufacturing and in preference to recycling, salvage, and disposal should be considered to be part of the design and critique of such systems as they are first construed. One needs to ask what are the barriers to such reuse? Clearly, there are those in enterprise who prefer to see every perceived need for technology answered with something newly produced and purchased – software can be one of the tools of such ambitions, as I described for the case of Vista above.

In a survey I conducted with some colleagues – namely Youn-Kyung Lim, David Roedl, and Erik Stolterman – of 435 undergraduates in October 2006, more than two-thirds said that given a fixed amount of money they would consider buying a higher quality used car (71%) over a new one (29%), but when asked about the purchase of a laptop given a fixed amount of money more than two-thirds said they would more likely buy a new laptop (72%) over a higher quality used one (28%). The responses given by the participants were about the same as for laptops for similar questions about cell phones and mp3 players. When it comes to electronics and computing devices, the rapid pace of technological change appears to cause more rapid depreciation in the perception of this age group.

From the perspective of critical design, the challenge is to figure out how to make interaction design contribute to reuse in preference to remanufacturing, recycling, salvage, and disposal. One way to accomplish this would be to promote high quality product forms, materials, and fashion that make products more valuable as ownership transfers.

The Apple iPod stands in sharp and enigmatic contrast to other products and to any rational concern for sustainability. It has high quality form and fashion appeal, and yet it has very rapid obsolescence as a matter of design. As an icon of interaction design, there are few things more worthy of iconoclastic action. Introduced in 2001, to date, Apple has sold 67 million iPods, in nearly a dozen variants of four models. The early models were designed to be discarded or *exchanged* when the rechargeable battery could no longer be recharged, a feature changed only in response to *consumer* pressure. The history of the iPod is nicely charted in a wikipedia article on the topic.[21]

It may not be specifically wrong from the perspective of sustainability for Apple to sell 67 million of its iPods nor even to *improve* its products over time, but the acceptance or ignorance of responsibility for what happens to used, disposed, and *yesterday's* iPods must be clearly understood to be part of Apple's design practice. Moreover, whereas there are many people who should accept responsibility – so-called consumers, marketers, engineers, industrial designers, executives – I claim that interaction designers need to be among the first to embrace their roles and responsibilities and learn ways to make the environmentally sound fate of these 67 million objects a clear part of their agenda.

In case there is any doubt about the role of interaction designers and digital materials in driving the design of the iPod, consider the following extract from the wikipedia entry cited above:

> Apple focused its development on the iPod's unique user interface and its ease of use, rather than on technical capability, which has been criticized for not including certain features such as radio. For simplicity, media files are not managed on the iPod itself but instead take advantage of Apple's jukebox application, iTunes. The software now runs cross-platform on Apple's Macintosh computers and competitor Microsoft's Windows operating system, as do recent iPod models, and is available as a free download

> from Apple. It stores a comprehensive library of music on the user's computer and can play, burn, and rip music from a CD, and serves as a browser for the iTunes Store, all of which can be done without an iPod. However, iTunes is required to sync media files to an iPod.

Elements of alternatives to the iPod approach seem simple to state, and difficult to implement – that is, Apple and other companies have shown that it is easy to design desire for new things. People like to acquire new things, but people also like high quality things and have pride in ownership. Therefore, try to create high quality enduring things which preserve their value over time and in transfer of ownership, rather than easily obsoleted disposable things. Try to find business models that enable companies to make ongoing profits from digital rather than physical materials, or from the care and maintenance, rather than designed obsolescence, of high quality things. Make it culturally unfashionable and politically unsupportable to maintain a culture of disposable computing devices or to consider passing low quality cast-offs from one-to-another or to the so-called developing world instead of high quality enduring ones. Moreover, the iPod and iTunes system prove that many people are willing to pay modest amounts for digital materials that are easily acquired freely, even if not legally. This is the real lesson of the iPod from the perspective of sustainability. It can hopefully inspire business models which substitute enduring and environmentally neutral digital content materials for the disposable and environmentally hazardous materials of rapidly obsoleted electronics.

As one of the anonymous reviewers of the conference paper gracefully suggested in summary,

> sustainability [should be] more than just recycling, and indeed [must become] a cultural paradigm shift away from technology novelty and induced consumption, toward an aesthetic of well-cared-for systems.

6. **the material effect of achieving longevity of use** – does the design allow for long term use of physical materials by a single owner without transfer of ownership, directly or indirectly, and even if the primary material of the design is digital material?

From the perspective of design criticism, the opportunities for achieving longevity of use of systems that embed the materials of information technologies without the need for remanufacturing and in preference to recycling, salvage and disposal should be considered to be part of the design and critique of such systems as they are first construed. The material effect of achieving longevity of use goes hand in hand with reuse as is – both have better environmental implications than the prior elements of the rubric and indeed achieving longevity of use is necessary to promote a culture of reuse-as-is, in which old things are valued as much, nearly as much or more than new things. The material effect of *reuse as is* is the material effect of *achieving longevity of use* with transfer of ownership.

From the perspective of critical design, the challenge is to find ways in which interaction design can promote longevity of use. This means that interaction designers need to find ways to ensure that software and interactive devices are designed to promote the enduring qualities of the physical materials associated with digital ones, rather than prompt early disposal or other forms of obsolescence. Keys to accomplishing this include awareness of quality in preference to features and invention – creating *an aesthetic of well-cared-for systems* in the words of the reviewer quoted above.

The Leica Module-R is a good example of an approach to the material effect of achieving longevity of use with the materials of digital technology. The Module-R can be substituted for the film back on certain Leica reflex cameras, converting them from film to digital operations and allowing them to be turned back again into film cameras. In spirit, this is a great example of backwards-compatible design that preserves old materials, which in this case are the highest possible quality ones. In practice, there a number of problems that need to be overcome in the future. First, the Leica Module-R was a very late entry into the digital marketplace, and the Leica company had a hard time because of its insistence on standards of quality and backwards compatibility.[22] Second, the approach is not competitive with other products, especially in terms of price. Third, the approach seems to have only been tried with high-end professional products, which may indicate that similar approaches are less practical for *consumer* markets. Finally, although reflex Leica camera bodies are all compatible with camera lenses going back to 1963, the Module-R is only compatible with certain camera bodies produced since 1996 and not earlier.

Another example of an approach to the material effect of achieving longevity of use is the Canadian company Suissa Computers[23] which produces extravagantly finished wood case high-end computers that are the aesthetic opposite of disposable ones. In addition, service and upgradeability are part of the marketing strategy. The products illustrate that if great care is taken with the design and choice of physical materials, the result may be a product that will endure and be upgraded rather than discarded. In practice, there are problems with this example as well – the use of expensive woods in computer cases may not be the most sustainable act, and the product is targeted at a luxury market making it seem an unscalable solution both from the point of view of wide distribution and use of resources.

The use of modularity and quality materials in the physical forms of these two examples are two ways to imagine achieving longevity of use that are nonetheless problematic. In addition, there are typical business marketing models to be confronted such as the tendency for parts or components to be priced more highly than whole systems. Another important issue is how to prioritise different environmental impacts – for example, at what point does acquiring a new item designed to use less energy make more sense than preserving the older, less energy efficient version? This is not often clear, and the information needed to make such choices is often unavailable. Overcoming these barriers is a critical task for sustainable interaction design.

7. **the material effect of sharing for maximal use** – does the design allow for use of physical materials by many people as a construct of dynamic ownership, directly or indirectly and even if the primary material of the design is digital material?

From the perspective of design criticism, the opportunities for designing systems that embed the materials of information technologies in a manner which promotes sharing for maximal use and therefore minimal environmental impact should be considered to be part of the design and critique of such systems as they are first construed. The material effects of reuse-as-is and achieving longevity of use are both typically preferable from the perspective of sustainability to the material effects of remanufacturing for reuse, recycling, salvage or disposal. The material effect of sharing for maximal use is again preferable in the usual case, since it suggests the most efficient use of resources.

From the perspective of critical design, the challenge is to find ways in which interaction design can promote sharing for maximal use. At the very least, if more than one person can share something, the environmental cost of producing that same thing is minimized over the cost of producing that thing for each individual.

Mark Weiser – credited with inventing the notion of ubiquitous computing[24] – has several patents relating to *dynamic ownership*, by which is meant systems for allowing ubiquitous computing resources to be shared dynamically between different people.[25] Regardless of whether or not Weiser ever regarded his concept in terms of sustainability, dynamic ownership is an interaction design concept that promotes sharing for maximal use. In conversations with colleagues who work in the area of ubiquitous computing, I learned that this particular concept has not yet been developed to its full potential. This seems like an important concept for interaction designers to take up from the perspective of sustainability.

Jennifer Mankoff, of the HCII institute at Carnegie Mellon University, has proposed[26] that a particularly good example of how interaction designers can focus on sustainability is to build central servers that monitor and synchronize the state of instant messenger accounts. Some of the most popular instant messenger programs apparently rely on and motivate people to keep their computers turned on or turned on in standby mode in order not to miss any messages. This is a form of energy use concealment that can be prevented by the use of central message monitoring and synchronization services. This proposal is another instance of sharing for maximal use, in this case with the potential to save substantial amounts of energy. Prof. Mankoff has also begun a social networking project to help people learn how to reduce their ecological footprints.[27]

8. **the material effect of achieving heirloom status** – does the design create artifice of long-lived appeal that motivates preservation such that transfer of ownership preserves quality of experience, directly or indirectly, even if the primary material of the design is digital material? This notion of heirloom status is similar to Nelson & Stolterman's[28] description of "ensoulment".

From the perspective of design criticism, the opportunities for achieving heirloom status for systems that embed the materials of information technologies should be considered to be part of the design and critique of such systems as they are first construed. Heirloom status promotes longevity of use and reuse-as-is. Few of the physical materials associated with digital materials seem to achieve this status. This stands in sharp contrast to many non-digital products.

From the perspective of critical design, the challenge is to find ways in which interaction design can take the notion of achieving heirloom status into account in the practice of interaction design. If a dress, pen, watch or an item of jewellery can be made to have heirloom status, what would it take to make an mp3 player with similar status?

One of the most wonderful photographic projects is Peter Menzel's *Material World: A Global Family Portrait*[29] which presents portraits of exactly average families from 30 countries throughout the world. In each portrait, a family stands proudly with their possessions arrayed in front of their home. Not only are great disparities in wealth revealed by comparing one portrait to another, but differences in what is valued are also illustrated in the variances from one household to another. Since the book appeared in 1994, computers are not present in the portraits. One wonders what Menzel's portraits would look like now. Would the physical materials associated with digital technologies figure prominently? Menzel's photographs show a material divide and the remarkable sense, in my view, that those with fewer, more enduring possessions seem closer to nature and less stressed than those with many.

9. **the material effect of finding wholesome alternatives to resource use** – does the design eliminate the need for the use of physical resources, while still preserving or even

ameliorating qualities of life in a manner that is sensitive to, and scaffolds, human motivations and desires?

From the perspective of design criticism, the opportunities for finding wholesome alternatives to use by means of systems that embed the materials of information technologies should be considered to be part of the design and critique of such systems as they are first construed. Are there ways in which the need for material things or cultures of materialism can be eliminated by judicious interaction design? Can interaction design serve to inform and motivate alternative ways of being that cause less environmental damage, and lead to sustainable, indeed richer and more fulfilled lives? On the other hand, to what extent does interaction design play a role in promoting the use of physical resources, cultures of materialism and misplaced senses of need? How can such roles be un-concealed?

From the perspective of critical design, the challenge is to take the notion of 'wholesome alternatives to use' into account in the practice of interaction design. In some sense, the core competence of practicing interaction designers can be thought of as making information more easily shared and available. Information is awareness and awareness of information about sustainable ways of being is ecological hope.

The availability of information on the internet makes learning certain things easier. For example, information on the internet can help me to understand if it would be better from an environmental point of view to buy a new hybrid electric vehicle or convert the 15 year old Mercedes I already own to run on propane and how to do so, or it can help me to find a way of living where I don't need to use a car at all. On the other hand, it is often hard to assess the quality of internet information and there is no reason that any particular person will use that information to establish sustainable behaviors.

Information technologies can assist in finding wholesome alternatives to resource use by making possible paperless journals, providing a conduit for the information needed to live off-the-grid, removing the effects of physical distance on communications, allowing for telecommuting, allowing for less travel in general, and so on. On the other hand, information technologies can also provide a conduit for doing exactly the opposite, driving consumption, and promoting inequity.

10. **the material effect of active repair of misuse** – is the design specifically targeted at repairing the harmful effects of unsustainable use, substituting sustainable use in its place?

From the perspective of design criticism, the opportunities for active repair of misuse by systems that embed the materials of information technologies should be considered to be part of the design and critique of such systems as they are first construed.

To what extent can such systems be purposed to undo prior acts of unsustainability? To what extent have such systems already contributed to acts of unsustainability?

From the perspective of critical design, the challenge is to find ways in which interaction design can actively repair misuse as part of the practice of interaction design. How can interaction design be used to inspire ways of undoing prior acts of unsustainability?

How bad is our present circumstance? In the conference paper, I provide the following assessment:

> In Kumar et al.,[30] an equation due to Graedel and Allenby[31] is set in contemporary terms – that is from a global perspective
>
> $I = N \times P \times E$
>
> where the total impact, I, of energy consumption, material resource use, and waste production is defined as a product of the population size N, the Gross Domestic Product (GDP) per capita P, and the specific impact as a measure of eco-efficiency which may be understood as energy use per GDP per capita E.
>
> Based on figures from the International Energy Association (IEA) and the Union of Concerned Scientists (UCS), Kumar et al. make predictions that the earth's population N will increase by a factor of 2 to 10 billion by the year 2050, and that GDP per capita P will increase by a factor of 5, conservatively stated. Thus, in order only to do no more harm than we are already doing to the environment, we need to reduce energy use per capita E by a factor of 10. Kumar et al. further point out that the improvement in efficiency in the use of energy over the last 100 years has only been a factor of 2.5, that faith in technology as usual cannot succeed, and that new thinking is critical to our survival.
>
> For the scientific community, these predictions are not at all controversial.

The prior nine elements of the rubric are all targeted at understanding how to do no more harm than we already do. This last element is targeted at undoing the harm we have already done.

It is much harder to give specific examples of the material effect of active repair of misuse. In writing about disposal above, I referenced Ubuntu and Xubuntu. The example of these systems raises many questions: How good would Ubuntu have to be for people to actually prefer an operating system designed to minimize the need for material resources? What is the role of interaction designers in making such preferences prevail? Are there alternative models of commerce that can be offered to make it impossible for software and hardware companies not to participate? Is open source such a model?

Five Principles of Sustainable Interaction Design

The rubric of material effects provides a classification scheme and a frame for discourse. In this section, I repeat several design principles proposed in the conference paper which are in a sense targeted at providing ways to design preferences for some effects over some others. These principles which can serve as both frames of design criticism and critical design goals for SID and they are here elaborated to indicate both senses. They are:

(i) *linking invention and disposal* – (a) which in the *critical design sense* is the idea that any design of new objects or systems with embedded materials of information technologies is incomplete without a corresponding account of what will become of the objects or systems that are displaced or obsoleted by such inventions, and (b) which in the *design criticism sense* is the idea that understanding the effects of recent or imminent inventions entails understanding what has and might be displaced or obsoleted by such inventions and how such things will, are, or have been disposed;

(ii) *promoting renewal and reuse* – (a) which in the *critical design sense* is the idea that the design of objects or systems with embedded materials of information technologies implies the need to first and foremost consider the possibilities for renewal and reuse of existing objects or systems from the perspective of sustainability, and (b) which in the *design criticism sense* is the idea that understanding how to promote renewal and reuse entails understanding why invention and disposal is more common;

(iii) *promoting quality and equality* – (a) which in the *critical design* sense is the idea that the design of new objects or systems with embedded materials of information technologies implies the need to consider *quality* as a construct of affect and longevity, and *quality* in the sense of anticipating means of renewal and reuse, thereby motivating the prolonged value of such objects or systems and providing *equality* of experience to new owners of such objects and systems whenever ownership transfers, and (b) which in the *design criticism sense* is the idea that things of poor quality invite disposal and are unsuitable for bridging social divides; and that the aesthetics of disposablility is a barrier to sustainability and equality;

(iv) *de-coupling ownership and identity* – (a) which in the *critical design* sense is the idea that the virtual world has irrevocably changed the way in which ownership of information and in particular ownership of personal identity are constructed and secured and that alternative notions of ownership and identity have design implications for sharing materials, intellectual commons, and sense of self-hood which must be considered as part of sustainable design of interactions with digital artifice, and (b) which in the *design criticism sense* is the idea that the ways in which people seek personal things to define who they are comes at the expense of personal security and the sharing of resources as part of a sustainable future;

(v) *using natural models and reflection* – (a) which in the *critical design* sense is the prospect that there may be an approach to interaction design – even by the design of its removal – that prompts sustainable relationships to nature and that SID begins with a reflection on this principle of making the world of the artificial more like the natural world with respect to sustainability, and (b) which in the *design criticism sense* is the idea that the ways in which our interactions with information technologies promote the unnatural aspects of the artificial are the ways in which interaction design promotes the unsustainable.

Future Directions

The conference paper gives examples for the first two principles described above. In future contributions, I plan to provide additional discussion and insights about each of these principles.

On the one hand, the HCI constituency is an active participant in the infrastructure of present technological, political, cultural, and economic conditions – as such, what can be understood by the discourse of DPP needs to be set in terms of outcomes that are operationalizable, even when what needs to be operationalized is the undoing of what has been done. The HCI constituency produces interaction designers who produce actual digital products within the economic and political machinery that exists now – to make the future more *viable* than the now, we need to provide the tools for *designing otherwise*. I refer here to concepts of *viable futures* and *designing otherwise* which owe to Tony Fry. For many in the world of interaction design practice, there is little time for the luxury of nuance and nuance needs to embedded in the tools themselves. The luxury of nuance has an environmental cost in terms of delays to acting and designing otherwise.

On the other hand, outcomes that owe to the critical vantage point of the DPP community are vital acts of reflection which have larger political and philosophical implications beyond interaction design. There are opportunities here for influence, for design philosophy to be an agency of change towards the sustainable by providing the tools of reflection in a form that can be adopted by proponents of sustainable interaction design with the HCI community. This is a community that has demonstrated its acceptance of new ideas over and over again. Jennifer Mankoff's Ecological Footprints[32] initiative mentioned above is a good example of this receptivity.

It is my hope that many new readers will come to DPP as a result of the conference paper. The conference paper is a first seed of cross-fertilization and a signal identifying DPP as an essential source of sound insights that can effectively inform notions of sustainability within HCI. This present paper continues that mission.

Notes

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