

Exploring Sustainable Design with Reusable Paper

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ABSTRACT

This paper explores the need for sustainable design with paper: how people really print and how we can take advantage of novel, reusable paper technology. We conducted two studies to investigate user's printing behavior. A key finding of the first study was that users often need an intermediate state between the electronic and physical forms of their documents. The second study examined users' predictions of which types of documents required this intermediate state. We formulate these findings into design guidelines that take into account: *examination phase, transitions, cognitive and emotional reasons, and task- and event-relevant documents*. Finally, we discuss how the different physical characteristics of reusable paper affect the user interface and could effectively support sustainable design.

Author Keywords

Sustainability, reusable paper, sustainable design, printing

ACM Classification Keywords

H.1.2 Models and Principles: User/Machine Systems—*Human factors*; H.5.2 Information Interfaces and Presentation: User interfaces—*Evaluation/methodology*

General Terms

Experimentation, Human Factors

INTRODUCTION

We all waste paper. Piles of papers lie on our desks, ready to sort, process, file or throw away. We print multiple versions, just in case. We annotate, fold, and attach post-it reminders. Yet, according to Steve Hoover at Xerox Research, some 50% of the paper we print is thrown away the day we print it. Far from early predictions of the paperless office [6], we are inundated with paper: typical American office workers use about 10,000 sheets a year¹.

¹ <http://eetd.lbl.gov/paper/html/concept.htm>

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We are interested in the problem of sustainability with respect to documents as they move back and forth between paper and electronic forms. We normally think of documents as either electronic or physical and use printers and scanners to transition between them. However, we can also use Anoto technology [3,4] to turn paper into an input device for the computer. E-books, such as Kindle DX and Sony's Reader Touch Edition™, are approaching paper's thinness as display devices. Truly interactive paper is still in the labs, but is coming: Xerox's Reusable paper² is explicitly designed for same-day, read-write use and technologies such as Anoto and E-ink could be combined to achieve similar results.

Our goal then is to examine the design issues surrounding such technologies from the perspective of the user and to identify the characteristics they require to encourage sustainable printing behavior. Blevis [2] argues that designers should carefully consider how interactive technologies can be used to influence sustainable behavior of users. We see two possible strategies: either create *active* interfaces that enable users to make conscious choices about saving resources or create *passive* interfaces that offer sustainable alternatives to the user's regular technology. The advantage of the latter is that passive interfaces do not require enlightened users, they just need to be used.

This paper explores the question of how to design the next generation of interactive paper to support sustainable use. We first describe a study that gathered specific examples of how people print documents. We then describe a longitudinal on-line study that logged every printed document and asked users to explain and reflect upon the details of their print behavior. We conclude with implications for reusable paper design and directions for future research.

INTERVIEW STUDY ABOUT PRINTING BEHAVIOR

We were interested in learning more about how researchers print, including how they choose which documents to print and the life cycle of those documents. We were particularly interested in the transition between the electronic and paper versions of documents.

Participants: We recruited 11 researchers, eight of whom worked mostly on-line and three who worked off-line.

² <http://www2.parc.com/hsl/projects/gyricon/>

Method: We conducted semi-structured interviews in the participant's offices, focusing on specific examples associated with three types of printouts; *batch printing*, when a variety of different documents are printed at once, *repetitive printouts*, when variations of the same document are printed in succession, and *short-life cycle printouts*, when documents "expire" shortly after being printed.

Results

Deciding what to read: Most, 9 out of 11, browsed research articles on-line, looking for cues that a paper might be relevant. The decision to print was quick and sometimes wrong: "I thought 'This might be interesting, I'll have to read it in more detail'. But when I read it, I saw almost immediately that it was not helpful." All reported having printed articles that they threw away when they later realized the document was irrelevant.

Comparing data: Three participants printed articles because comparing graphs on paper was easier than trying to manipulate them on the screen. "As you can see, my screens are very large, but looking on two desktops is really hard. So I printed it out to compare graphs."

Annotating and finding errors: Three participants repeatedly printed out versions of the same document to make modifications and preview the results. "[if] I am working on an article, I print the current document and after I write several corrections, [...] I change the document and print it again." "Often when I proof-read, I just print it. I might look through it quickly, to see what I want to change."

Security: Printing interim versions served as a physical backup of earlier versions, in case something was lost. "I like to have printed copies, so if I make changes I have some kind of physical backup. [that] I can easily see, this is the way it used to look before. [...] Often, it is less that I need something on paper but rather that I need to find it again."

Remembering to act: Three participants printed articles as a reminder, either to read it in detail or to include it in the references section. "Yesterday I printed an article [...] but in fact I forgot to read more, because I had something else to do." "I often see a paper and want to talk about it. [...] I would not remember it again, [...] because I don't think about it. But if it is in the pile, then just by looking through it for other things, I see this paper."

Refinding documents: Five participants admitted that they sometimes reprint documents because they cannot find the previously printed version. Two said that it was easier to find the same paper again on the web, whereas two others developed their own systems to keep track of their physical papers. "I merge all my documents together to create a little book. [...] I have this big folder with a lot of articles and I print the first page of each article. I put them on a little card to make a little book with all the first pages for

each paper. So I can take the card [...] and see the reference, 'Ok, it is there in my folder'."

Participants also discussed how they felt about their print behavior, becoming embarrassed in some cases at how much paper they waste. Six participants said they would only print parts of long documents, e.g., over 50 pages, and they used the backs of no-longer-relevant documents as scratch paper. Seven participants described how reading on paper is a different experience than reading on the screen and five said they printed documents when the article was difficult to understand.

DISCUSSION

Examining users' print choices revealed several situations specifically amenable to sustainable design. Sometimes the user is in a hurry and does not know in advance which documents will be useful. In such cases, they often resort to *batch* printing of a large number of documents, after which they throw away those that are unnecessary. Some of these printouts could be avoided by *postponing the printout decision*. Another common situation is when the user *transitions* between electronic and physical forms of the document, because tasks like proof-reading and comparing data are performed differently in the two media. We also noted that some users print for *emotional* reasons: they are worried about *forgetting* or *losing* the electronic version of the document. Others print for *cognitive* reasons, to gain a different perspective when reading on physical paper.

ONLINE PRINT STUDY

Most studies of print behavior are based on diaries or ethnographic studies. We were interested in obtaining a complementary view by collecting longitudinal data and asking people to reflect upon their actual print behavior in the setting in which they print. We were also struck by how awkward people felt about admitting that they wasted paper. We thus felt that an online questionnaire would be both more systematic and allow users to be more honest.

Participants: We recruited nine researchers. Eight came to the office everyday, one came only occasionally.

Method: We ran a five-week study in which we logged the print jobs of each participant and asked them for details about each printout. Using a variation of critical incident technique [4], we sent a daily reminder to run a logging program that captured the names and times of each job that had been printed that day. We then opened a short questionnaire, one per print job, and asked for details about each printout. We asked for estimates of the amount of time they had spent on the paper documents currently on their desk and what specific tasks were involved with the printout. We also asked how they planned to further process either electronic or paper versions of the document, why they chose to print it and what physical benefits influenced their printout decision. If documents with the same title were printed several times, we displayed them as a list and asked for an explanation of why all were printed.

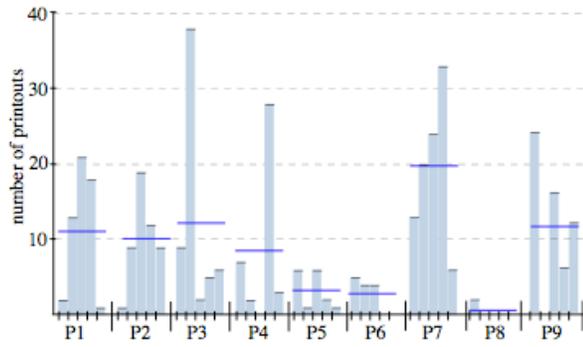


Fig. 1. Number of print jobs per week, over five weeks, per participant (P1-P9). Mean is indicated with a blue line.

Results and Discussion

Participants printed an average of 10.5 documents per week, although this was highly variable, as seen in fig.1. The study included 426 print jobs, with 131 explanations (81 complete). We created task categories for each type of printout, as shown in fig. 2-a.

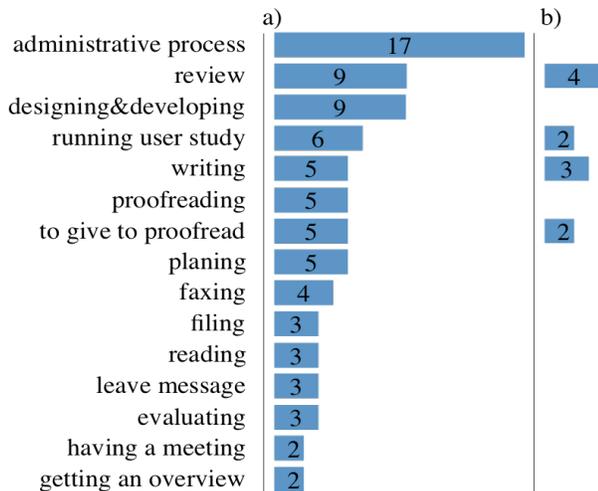


Fig. 2. a) Number of printouts per task.
b) Number of repetitions per task.

We noted how users further processed electronic and printed versions of documents and how long they used a document before switching to another task. We also asked for details about the document, to help us categorize it. We found that participants printed 44% of their documents for future annotation; only 7% were printed solely for reading. Participants also printed to compare sheets (12%), sort (6%), preview (5%) and access (1%). Another 26% were printed because the user needed to go somewhere else.

Classifying documents: We found conventional classifications little help in determining how to integrate dynamic reusable paper technology: they either categorize documents based on the time spent on desktops [1] or their status in the user’s workflow [6]. Calculating how long a “temporary” document should be kept is difficult. For example, one might expect that annotated documents for

which comments had already been integrated or maps to past events could easily be thrown away. While usually true, users also saved such documents as reminders as to which corrections were made or as a souvenir of the event. This suggests that users might take advantage of reusable paper with a memory, e.g. to find earlier drafts of the same document or a recent map. On the other hand, ‘sentimental’ printing, when the physical document acts as a souvenir of a person or an event, is likely to require regular paper.

We identified three document categories that affect sustainable printing: *task-relevant*, *event-relevant* and *unpredictable*. Task-relevant documents may no longer be required after a task is completed: once the items on a shopping list are purchased, the list is often thrown away. Similarly, event-relevant documents may no longer be required after the event occurs: after a project meeting, the agenda is often thrown away. These documents are predictable: users know when it makes sense to throw them away. We also identified an ‘unpredictable’ category, in which users do not want to decide in advance when to throw out a document. For example, archived bank statements will become unnecessary at some unspecified time in the future. Even so, they are printed and kept ‘just in case’.

Predictable documents: When users can easily predict the circumstances under which a document will be thrown away, they can be confident about placing it in a temporary form to avoid unnecessary printing. Task- and event-relevant documents are thus likely candidates for reusable paper. Table 1-a shows nine tasks that use a single document type. Table 1-b shows the distribution of document types when tasks are mixed. We found that approximately 42% of documents were seen as *task-relevant*, 26% were *event-relevant* and 32% were *unpredictable*.

	task	N	task-rel.	event-rel.	unpredictable
a)	review	9	100%	-	-
	get overview	2	100%	-	-
	meeting	2	100%	-	-
	proofreading	5	100%	-	-
	reading	3	100%	-	-
	give proofreading	5	100%	-	-
	planing	5	-	100%	-
	leaving message	3	-	100%	-
	filing	3	-	-	100%
b)	run user study	6	50%	50%	-
	writing	5	20%	80%	-
	evaluating	3	33%	-	66%
	faxing	4	75%	-	25%
	admin. process	17	11%	41%	47%
	design&dev.	9	66%	22%	11%

Table 1. a) Nine tasks used only one document type category.
b) Six tasks were distributed across categories..

Repetitive vs. duplicate printouts: After omitting printer errors and misinterpretations, such as two documents with the same file name, we checked duplicate printouts for a particular task (fig. 2-b). For example, one researcher printed successive versions of a document, and then printed an extra version to read on her way home. Most repetitive printouts were actually iterations of a submission, based on proof-reading comments from various colleagues.

REUSABLE PAPER TECHNOLOGY

We consider both commercial E-books (Kindle, Sony's E-book reader) and research technologies, Xerox's reusable paper and E-paper, with respect to sustainability (Table 2).

Technology	Content lifetime	Weight	Update power?	Erase power?
E-book/ink	long	290g-600g	Yes	Yes
Reusable paper	16 hrs	as paper	Yes	No
E-paper	long	as paper	Yes	Yes

Table 2: Comparing reusable paper technology

E-books are long-lasting, portable and user-erasable. They use E-ink, which places tiny black/white orientable balls in the ink substrate covering the paper. E-books only require power to update the content; otherwise, the display is stable without power. E-books are encased in a lightweight frame but the sheets are only 1cm thick and weigh 290-600g.

Xerox's reusable paper is ordinary lightweight paper treated with a light-sensitive material. Content appears after being exposed to a specific wavelength of light (the 'printer'), but is very unstable, auto-destructing after 16 hours. Annotating this paper with a conventional pen renders it unusable.

Xerox's E-paper consists of a grid of pixel-sized cells, which display black or white according to the voltage applied to each cell. The resulting long-lasting images remain until the user explicitly erases them. E-paper is lightweight, portable and could be annotated with an electronically charged pencil.

Different technical characteristics offer different opportunities for sustainable design. Xerox's reusable paper makes sense when users know that the content is very temporary. However, we found few suitable tasks for this, since our users wanted more control over when the paper was erased. Both the E-ink-based and E-paper technologies let users defer erasing decisions, allowing them to stay in an intermediate state as long as needed, thus increasing the likelihood of sustainable printing behavior.

IMPLICATIONS FOR DESIGN

Our studies suggest that the specific physical characteristics of reusable paper will affect the user interface and thus influence sustainable behavior. We identified the following:

Examination phase: Just as people leaf through books before buying them, sustainable paper interfaces should permit an examination phase that postpones printout decisions. This phase could encourage users to reflect on when they actually need paper printouts, letting them actively choose more sustainable print behavior or even forcing them to print first on reusable paper. For example, researchers could first print articles on reusable paper and only print on regular paper if they decide to save the article. In this case, reusable paper must offer the physical benefits of paper and not self-destruct.

Transitions: Reusable paper technologies help address the intermediate transition state between electronic and paper

documents. The technology should offer the user a choice between *explicitly* or *implicitly* printing an electronic document on regular or reusable paper. When the choice is explicit, users will decide on a document-by-document basis. However, in some situations, such as batch printing articles to review for a conference, the user should be able to print on reusable paper and then return to regular paper.

Cognitive and emotional aspects: Users should be able to search and easily access documents that were once displayed on dynamic reusable paper, to reduce fear of loss and of forgetting. The technology should provide user-controlled change of content and remain stable over time. Users should be able to spread out and align sheets of reusable paper, just as with regular paper.

Task- and event-relevance: From a user's perspective, it is usually easy for them to predict when task- or event-relevant documents will no longer be needed. The technology should allow users to select between regular and reusable paper, taking into account their confidence about the document's usefulness over time. We believe this will increase the likelihood that they will choose reusable paper when it makes sense and encourage sustainable behavior.

CONCLUSION AND FUTURE WORK

This paper explores how users print documents and the implications for incorporating reusable paper technology into the printing process. Decisions about what and when to print are complex and involve a variety of factors. However, we found that, for some document categories, users move into an intermediate state, between interacting with an electronic document and archival printing, for which reusable paper technology is ideal. If users can predict which documents will enter this intermediate state, we suggest that they will be more likely to choose reusable paper and thus engage in more sustainable printing behavior. The specific physical characteristics of reusable paper will thus affect both its use and its sustainability.

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