

Digital Pen: Four Rounds of Ethnographic and Field Research

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Abstract

We report on a year-long qualitative and ethnographic project to examine the value of digital pen technology for note taking. A digital pen captures a facsimile of information written on specially patterned paper and makes it available for later review, management, data recognition, and archiving on a PC. We report ethnographic research on note-taking practices among US college students (N=19) and office workers in the US (N=12) and Japan (N=4). We review note-taking patterns observed in controlled laboratory research in the US (N=17) and Japan (N=8) and actual product usage in US field trials (N=15). Finally, we describe note-taking needs reported in enterprise site visits in the US, Japan, Canada, and India (N=28). We review behavioral barriers to adoption of digital pens, including lack of workflow integration, poor environmental availability, and cost. To increase its value to consumers, digital pen technology should cover more kinds of actual writing behavior.

1. Introduction

A “digital pen” (DP) is a ballpoint ink pen which, used on specially patterned paper, records a digital facsimile of whatever one writes [1]. The digitized writing may be downloaded to a PC to be filed, reviewed, printed, or converted to text. In this paper, we review a year-long research project that explored potential consumer uses for this technology.

The Anoto Group has produced an extensive developer platform for DP technology [1] and their technology has been commercialized by Logitech [12], Livescribe [11], and other device and solutions providers. Perhaps the most obvious use case for DP technology is general note-taking. For instance, students might take notes in a class notebook, or professionals might take notes during a meeting with colleagues or customers. However, adoption by consumers of DP for general note-taking has to date been very limited. In this paper, we review a series of overlapping consumer research studies and present findings that suggest why consumer adoption is low.

Other use cases for DP technology involve two general categories of usage. First is structured data collection, such as writing parking tickets, taking structured medical notes, or filling out an inspection form, where the information is linked to a specific workflow and database application. Second is annotation, where a printed document is marked up, corrected, or amended with digital ink. These are interesting and significant applications that we hope to report on in the future. For the present paper we limit our attention to note-taking applications.

In our usage, “note taking” with DP can be defined as follows: a consumer uses a DP device and paper to create written artifacts of any type for their own individual usage (either for work or personal purposes) and the digitized facsimile is downloaded to a PC for archiving or review by the writer.

There has been little published research on broad behavioral analysis of digital pen usage and related technologies for note taking. Prior research falls into three general categories: (1) paper-based interaction models for digital documents, such as marking up printed documents for editing or using paper as a control device (e.g., [6][7][10][13][17]); (2) DP-based applications that address specific, well-defined use cases, such as input of medical information [3] or user authentication by signature [18]; and (3) platform technologies that may be used to implement basic functionality or middleware for DP systems [1][5]. A separate research issue involves the psychological operation and impact of note-taking, apart from technological concerns (e.g., [8][9]); we focus here solely on the behavioral aspects of note-taking that are important for DP technology usage and design. To our knowledge, there has been no large scale exploration of basic note-taking behavior and the implications of such behavior for DP technology in general.

2. The Digital Pen Interaction Model

To understand user response to DP technology, it is important to examine several fundamental aspects of the DP interaction model and to recognize how these differ from the traditional pen and paper equivalents. (We describe the most common Anoto functionality

model here [1]; other DP systems have other interaction models, generally more restrictive than the Anoto model.) A digital pen comprises a ballpoint ink cartridge and a battery-powered, camera-based scanning system, packaged in a single unit that resembles a large ballpoint ink pen.

The pen detects location on paper by reading a pattern pre-printed on the paper using a proprietary encoding scheme. Briefly, this coding scheme allows the pen to know where it is on a page (X/Y coordinates) as it writes and to know which page it is on, among a large space of possible pages. Pages may be duplicated within this space; this points to one of the important differences between DP and traditional pen and paper usage. One mass-market DP product (Logitech io2 Digital Pen [12]) uses notebooks with pre-printed DP pattern pages, but every notebook with the same colored cover is identical. This means that, when one writes in two different notebooks with the same cover color, the DP product cannot distinguish which notebook one is using without other information. A manufacturer may address this “space management”

problem in various ways, for instance, by asking users to check a box whenever they switch to a different notebook or disambiguating content post hoc through timestamps or user inquiry.

DP patterned paper cannot reliably be reproduced; it must be purchased pre-printed, or, if the DP product supports this capability, printed on demand. Simply photocopying pages does not work reliably.

Notes taken with DP may be downloaded to a PC where they can be reviewed, archived, printed, or converted from handwriting to computerized text. The primary interface for such notes is simply viewing them as facsimiles of written documents, perhaps organized by date, topic, or keywords.

Finally, of course, users only benefit from the system when they take notes using both a charged and functional DP pen unit along with appropriately patterned paper. Using the pen on non-patterned paper, or writing on patterned paper with another ballpoint pen (perhaps indistinguishable in appearance), will result in no data collection.

Table 1: Summary of the digital pen HCI research activities

Research project	Location(s)	Participants	Sample size
Collect instrumented data on writing characteristics	US, Japan	Adult PC users	N=25 (US=17, JP=8)
*Ethnographic interviews: knowledge workers	US, Japan	Enterprise knowledge workers	N=16 (US=12, JP=4)
*Ethnographic interviews: college students	US	Full-time university students	N=19
Focus groups on usage scenarios	US, Japan	Adult knowledge workers	18 focus groups N=4-10 in each group
*Field trials of DP product: college students & knowledge workers	US	Full-time university students and full-time office workers	N=15 (7 students, 8 knowledge workers)
*Enterprise site visits	US, Japan, Canada, India	Enterprise IT administrators and end users	N=28 organizations (US=20, JP=6, CA=1, IN=1)
Usability studies on product form, patterned paper, and other aspects	US, Japan	Adult PC users	N=20 (US=12, JP=8)

* reported in this paper

3. Research Series

We investigated note-taking uses of DP through a series of multiple ethnographic interviews, usability lab studies, focus groups, field trials, and corporate site visits. A complete summary of the research activities is shown in Table 1. These research activities involved many different aspects of human-computer interaction (HCI), ranging from collection of detailed interaction data (e.g., instrumented

prototypes that collected data on stroke length, speed, pressure, and so forth), to ethnographic work on understanding patterns of writing in general, to investigations of value propositions for DP products.

We report here on ethnographic, laboratory, and field studies designed to determine the specific utility of DP products for individual users. For convenience, we divide the research into two general categories: consumer research, i.e., investigation of the utility of DP technology for individual users who might adopt

the technology, and enterprise research, in which DP technology might be adopted in order to meet corporate needs for record keeping or productivity. This is largely a heuristic distinction; there is no dividing line between individual and corporate note-taking. Operationally, the difference was whether we interviewed individuals about DP products they might personally purchase and use, or we interviewed groups of employees and IT administrators within a business organization about how the organization might use and deploy such technology.

The primary method reported here is a variety of ethnographic research to inform technology design [14]. In each of the three ethnographic series of research reported below, we conducted fieldwork including in situ interviews, workplace observation, and inspection and collection of written and printed artifacts. We did not engage in long-term ethnographic participant observation [4]. However, our enterprise studies involved multiple visits with several organizations; field trials of actual products were conducted longitudinally; and our own usage of DP products provided longer-term self observation. Thus, although many of the individual engagements and observation trials were relatively brief, they were numerous, iterated over time, and part of a long-term systematic research effort. We are covering several studies in this paper, so we report findings briefly rather than with deep individual ethnographic detail.

This research was conducted in 2004-5 as part of an investigation of platform technology that would support DP products. It has been embargoed until now for general presentation, but we believe that the research is still relevant; little has changed in DP technology since 2005. To our knowledge, our work forms the largest body of human-computer interaction (HCI) research into DP technology.

The research presented here involved detailed research of behaviors and attitudes but did not test directional hypotheses. Such research could be followed up with specific hypothesis testing, which would form an interesting additional research project.

3.1. Research Series 1: Consumer Ethnographic Note-Taking Samples

3.1.1. Method. 19 full-time university students in the Seattle, Washington, area were recruited and interviewed in depth about note-taking behaviors. Students were asked to describe all aspects of their note-taking activities, such as how they take notes in any medium (in notebooks, on handouts, on a computer, etc.); how they archive and review their notes; whether they rewrite, reorganize, or type their notes; how and if they share their notes; and so forth. We asked participants to show us multiple examples

of their notes, and to provide a copy of a complete set of notes taken during a recent class lecture. These sample notes were later reviewed and coded for length, writing style, and types of content.

3.1.2. Findings. Respondents reported mixing multiple kinds of content in notes (course notes, action items, personal notes, reminders, doodling, etc.) and also took notes on both dedicated papers (e.g., notebooks) and environmental papers (e.g., class handouts). Figure 1 shows an example of note-taking on a class handout. For a single class, notes ranged from 1-5 pages, with a mean of 3.7 pages (mode 4 pages, median 3 pages). A majority of students (11/19) mixed cursive and print styles during a single set of notes. 7/19 students included action items; 7/19 mixed personal notes with course notes; and 6/19 marked off sections that separated course notes from other materials. 10/19 students used a hierarchical outline method when taking notes, while the others used a free-form narrative style.

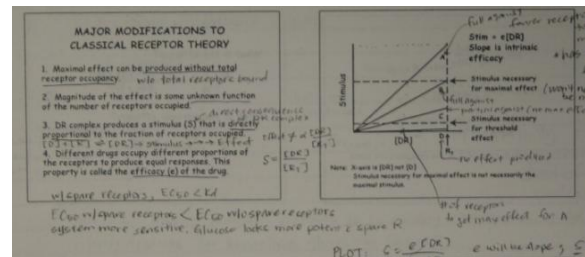


Figure 1. Example annotated class handout

Drawings or other graphical elements were included on 12/19 samples, and the proportion of a given note that was graphical ranged from approximately 5% of the note's content (95% text, 5% graphics) to as much as 100% (no text), with a mean of approximately 13% graphics. The most common graphics were arrows or lines illustrating conceptual relationships (present in 69% of content-related graphic samples), doodles and non-subject related drawings (54%), and charts or tables (23%).

Among textual elements, 15/19 included a subject heading, 10/19 were dated, 6/19 had strikeouts, 13/19 had subject-specific symbols (e.g., math or scientific symbols), and 4/19 had added highlighting. Among all of the noted action items (present on 7/19 samples), approximately 20% were personal and 80% were class-specific, while approximately 60% were demarcated from the other content and 40% were intermixed with class notes. 3/19 samples included multiple languages (a mixture of English and one or more foreign languages).

3.1.3. Implications for DP. These results suggest four important implications for DP technology. First,

the importance of environmental paper and handouts implies that a large portion of student notes will be unavailable to a DP system that relies up patterned paper; students' notes would be segregated into notes that are available on PC and paper, and those available only on paper.

Second, much of the content appears to be non-archival in quality, such as transient action items, doodles, and other personal notes. Indeed, some content, such as remarks about classmates, might be unwanted in an archive. Third, the widespread usage of drawings, arrows, doodles, outline methods, scientific symbols, and foreign languages means that automated text recognition would be difficult to implement and might have low accuracy.

Fourth, in many cases, the importance of notes appears to be more about their role as placeholders within a process (such as reminders), rather than as bearers of content as such. A DP system that implements content facsimiles without process integration will have limited value for those notes.

3.2. Research Series 2: Consumer Laboratory Note-taking Samples

3.2.1 Method. Adult native-speaking PC users in the US and Japan were recruited for one hour laboratory sessions to watch an educational documentary in their native language and take notes. Notes were taken with a ballpoint pen on regular notebook paper, mounted on a 9"x12" Wacom Intuos2 digital tablet which provided instrumented data on writing (not reported here). Respondents were asked to watch the documentary on DVD and take notes as if they were attending a lecture or conference, in whatever style they would customarily take notes. Sessions ended when one complete page of notes had been taken.

3.2.2 Findings. 17 respondents completed the US trials, and 8 completed the Japan trials. Examples of typical notes are shown in Figure 2 (US) and Figure 3 (Japan). As may be observed in the samples, there was significant cultural variation in note-taking: US notes tended to be sprawling and were frequently difficult for others to decipher, whereas Japanese notes were clearer and more organized. There were also substantial similarities: in both the US and Japan, notes were taken sequentially but frequently amended over time with additional notes, clarifications, callouts, or strikeouts; the information taken was brief and often mnemonic rather than fully descriptive or narrative; and diagrammatic elements were used frequently to illustrate relationships among concepts and to highlight important information.

3.2.3. Implications for DP. These note-taking trials demonstrate the potential value of DP technology. First, note-taking was observed to be primarily sequential with much attention to mnemonic function (highlighting important terms, calling out significant details, and so forth). Such notes serve primarily as documents to assist with information assimilation and memory triggering [8], rather than as textual repositories of narrative facts. The DP model yields facsimile notes that are appropriate for such review, and significantly extend it, as notes are simultaneously available on both paper and PC. In short, notes taken in this laboratory context were a better fit for DP than those observed ethnographically among student note samples.

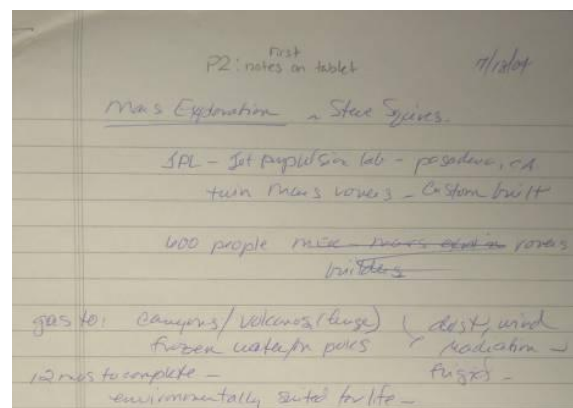


Figure 2. Example of US notes

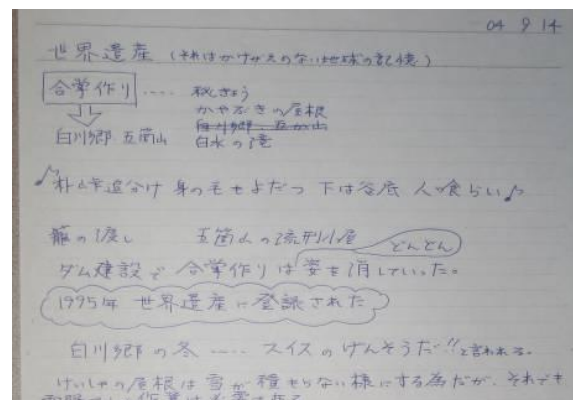


Figure 3. Example of Japanese notes

3.3. Research Series 3: Product Field Trials

3.3.1. Method. Participants from ethnographic interviews who had note-taking habits appropriate for DP technology were invited to participate in a month-long field study of an existing DP product. (Participants were judged to have "DP appropriate" note-taking behavior if they took detailed notes on a regular basis for school or professional purposes, archived the notes for later review, and expressed

interest in using a DP product.) Participants were given a Logitech io2 Digital Pen kit [12] and additional notebooks (approximate retail value US \$150), were observed during product setup, and were interviewed at intervals of one to two weeks and again at one month to determine their DP usage pattern. Follow-up interviews included discussion of how they used the DP product, benefits and limitations, review of notes taken with it, and changes in their note-taking behavior, including continued usage or abandonment of the product.

3.3.2. Findings. 8 full-time office workers and 7 full-time university students participated. After two weeks, 7/8 knowledge workers and 5/7 students had stopped using the DP product. Primary reasons they stopped were (a) the difficulty of keeping up with the special pen and paper; (b) the small importance of notes taken on dedicated paper, as opposed to the value of writing on handouts and other documents; (c) the limited value seen in reviewing notes on a PC instead of paper; (d) dissatisfaction with the accuracy of handwriting recognition – users frequently said that a digital system has little value unless it can automatically transcribe notes.

Among the 3/15 people who continued using DP, the primary value was to have an archive in case of loss of important handwritten documents, such as artistic sketches. After one month, no knowledge worker (0/8) and one (1/7) student continued using the product. The 7 college students were asked: if they lost the product, how much would they pay for a replacement? Most said they would pay \$10 or less, and none said he or she would pay more than \$25.

3.3.3. Implications for DP. The primary finding is that existing behavior with pen and paper fits most people’s needs well and is difficult to change. People experience significant advantages from the ability to use any paper, from any source, with existing pens; to be able to use existing writing devices with any paper-based document; the ready availability of pens, pencils, and paper in their common environments; and the low cost of traditional pens and papers.

Using DP requires attention to one specific pen and one kind of paper. Given the low perceived benefit of PC-based review of notes, most users had little incentive to engage in such a change in behavior. The low stated value and nearly unanimous abandonment of product usage in this trial imply that adoption of similar products would likely be low.

3.4. Research Series 4: Enterprise Site Visits

3.4.1. Method. The research team identified 28 organizations that represented a breadth of industries

that were expected either to be significantly interested in DP note-taking applications for individual employees (e.g., professional services) or expected to be largely uninterested (e.g., manufacturing). For each organization, the research team visited in person if possible (N=23) or scheduled conference calls with representatives (N=5). At each organization, the research team interviewed both individual knowledge workers and IT management who were responsible for knowledge worker productivity systems. The interviews surveyed organizations’ note-taking and retention practices, collected samples of hand-written artifacts, observed knowledge worker workplaces (when possible), reviewed DP technology, and inquired as to what they viewed as potential applications for DP in their workplaces.

3.4.2. Findings. The breakdown of organizations visited is shown in Table 2. Among the organizations, 8/28 expressed high interest in DP technology, principally in professional services, law, and education and research organizations. Common pen-related artifacts in those organizations were personal notes taken during meetings (either internal meetings or client meetings); action items, reminders, and to-do lists; and business-related drawings (charts, engineering drawings, architectural sketches, etc.)

Table 2: Summary of Organizations Visited

Line of business	US	Outside US
Finance	N=3	N=2 (Japan)
Insurance	N=1	N=1 (Japan)
Healthcare	N=3	N=1 (Japan)
Law	N=3	
Professional services and consulting	N=2	N=1 (India) N=1 (Canada) N=1 (Japan)
Transportation and manufacturing	N=4	
Education and research	N=2	
Government services	N=2	
Publishing		N=1 (Japan)

Organization size	US	Outside US
Medium (100-999 employees)	N=3	N=1 (Japan) N=1 (Canada)
Large (1000-9999 employees)	N=6	N=3 (Japan) N=1 (India)
Very large (>10000 employees)	N=11	N=2 (Japan)

The key benefits of DP technology were viewed as retention of information for intellectual property

backup, assurance of regulatory compliance issues (e.g., documentation for patents), and ability to search for information (assuming handwriting recognition within centrally archived DP documents).

Among work artifacts, we observed frequent mixture of work-related and personal information on a single piece of paper (for instance, meeting notes together with personal reminders). Notes were frequently taken on environmental paper (meeting handouts, the unprinted side of discarded documents, sheets of copy paper, note pads, etc.), and content freely mixed text and drawings.

In some cases, text was mixed between a native language and a foreign language or other linguistic context. For example, engineering and research organizations often included mathematical symbols; healthcare facilities used many abbreviations, drug names, chemical terms, and Latin phrases (themselves often abbreviated). In Japan, medical terms were often borrowed from German and English.

A frequent observation in business settings was the free availability and exchange of pens: people could expect offices and meeting rooms to have extra pens available such that there was little need to possess a personal pen. Participants also reported frequently losing pens.

Another striking observation was the sheer prevalence of paper documents. As Sellen & Harper noted in *The Myth of the Paperless Office* [16], paper provides an interaction model that is well optimized for many uses and appears to be growing, not shrinking, in importance as offices are increasingly handling digital documents. In many cases, we observed the sheer exposed surface area of paper documents in an office (e.g., the tops of document piles on a desk) to be many times the area of a PC screen.

We observed significant cultural differences between the US and Japan. In Japan, knowledge workers reported attending fewer formal meetings than in the US, and it was common for meetings to have a dedicated note taker – often a junior employee – who produced formal notes (minutes) for all attendees. Thus, individual note taking in meetings appeared to be less necessary in Japan than in the US, although the automation value of DP for the specified note-taking employee might be high.

Multi-color ballpoint pens appeared to be popular in Japan. In our individual sessions in Japan (Research Series 2 above), we observed all 8 participants to have three-color retractable ballpoint pens. Ink colors were used for idiosyncratic patterns of content differentiation, e.g., separating facts recorded in a meeting from personal conjectures by writing them in different colors.

This pattern of writing with color was also observed during our enterprise site visits in Japan and suggests that DP technology may need to provide a simple way to meet the need for ad hoc content differentiation that color provides. Finally, signatures in Japan are generally given with a personal ink stamp (“hanko”), not with a handwritten signature. This is a more important consideration for formal documents using DP than for note taking, but the need to implement a “digital hanko” was a common observation of participants.

We also observed user-perceived barriers that were specific to various lines of business. For instance, in the Japanese insurance industry, insurance agents are independent and sell policies for multiple companies; a single insurance company would find it difficult to require agents to work with proprietary DP technology. In US medical settings, a common concern was compliance with the Healthcare Insurance Portability and Accountability Act (HIPAA), which mandates stringent controls on information privacy. Organizations were unsure whether DP products would be HIPAA compliant, and even if the products themselves were secure, whether their onboard information could be kept secure when the pens are small and easily lost.

3.4.3. Implications for DP. Although there was substantial interest in DP technology among professional services and white collar organizations, the ethnographic findings suggest that delivering appropriate value from DP technology would be difficult. The first barrier would be providing a platform that either conforms to or changes current behaviors around pen and paper: free availability of pens and unpatterned paper in the workplace, behaviors of writing on environmental paper, and the need to keep up with a personal pen with one’s data.

The second barrier would be to meet expectations around text; much of the value was seen as being in retention and searching of textual information, but this would be made difficult by the frequent inclusion of acronyms, abbreviations, symbols, and foreign languages. Many organizations saw value in centralized repositories that would manage DP information across many employees; this would require an IT infrastructure that was not available (e.g., to manage the DP pattern space) and might be difficult and expensive to develop and maintain. It also poses questions about privacy, since employees might not wish the archive to retain personal information captured alongside work notes.

Finally, because we noted real or perceived barriers that were highly specific to various industries, it appeared that DP solutions would be most likely to succeed if they were tailored to very specific settings

and use cases. This does not argue against DP usage and its value, but it suggests that delivering value to organizations may require substantially more design and development effort than a single general solution or platform would provide.

4. Discussion

Our findings show that the interaction model of DP technology diverges substantially from common pen and paper usage. This divergence leads to unclear utility of DP for consumer note-taking purposes, and in a field trial, resulted in high abandonment rate of a consumer DP product. Among the most significant limitations were the low value seen in review of facsimile notes on a PC, the requirement with DP to use a special pen paired with patterned paper, and the low perceived value of capturing only notes taken on blank paper as opposed to handouts and other materials. In the enterprise space, the environmental issues were even more prominent due to the common infrastructure of freely available, communal pens and paper and the lack of IT infrastructure for DP document retention.

The note-taking research reported here suggests that writing behavior comprises many important areas besides capture, retention, and review of specific data. For instance, a single blank piece of paper or a one-word reminder may adequately serve as a reminder to do something that one intends, even though there may be little or no content as such. Likewise, in interpersonal contexts such as attending a lecture, it may be socially desirable to take notes even if they are later simply disposed. Taking notes may also serve purposes of memory consolidation even when the content is never reviewed [8][9].

4.1 DP and Writing Acts

Linguistic acts in social context have been described using a model of performative behavior commonly known as “speech acts” theory [15]. Chapman [2] extended that model to encompass writing, suggesting that many aspects of “writing acts” are unique and separate from spoken language. In the extended model, writing acts may be described with a multidimensional taxonomy encompassing a writer’s context, aspects of the process, type of content, and linguistic features of the content.

Table 3 summarizes the dimensions of writing acts (from [2]) and lists types of writing that exemplify each dimension. For instance, “separability” denotes the extent to which items in a document are logically independent of one another; in a contract, nothing is separable because the document is a single

piece, while on a to-do list, many or all items may be independent of one another [2].

DP technology may benefit from attention to the dimensions that are exemplified by writing acts embedded in social contexts. DP systems may be able to perform some kinds of writing acts quite well, but in other cases, DP may be inconvenient, unnecessary, or inappropriate. Models such as the writing acts framework can be used both to understand user behavior broadly and systematically to explore the applicability of DP products across the general space of writing behavior.

A key problem for DP in note taking applications is that note taking can involve nearly every possible dimension of writing acts. Notes may be separable or not; they may serve as functional content or as contextual reminders; they may present “just the facts” or be more interpretive; they may be transient or might be intended to be archival documents; and so forth. In short, notes are able to present a vast array of writing styles that pose substantially different value propositions and technological implications for DP products. Delivering a general DP solution for note taking may therefore be expected to be difficult.

Table 3: Dimensions of Writing Acts [2]

Dimension	Exemplars
Separability	a contract vs. a to-do list
Function	a typed inventory list vs. calligraphy
Emotionality	a love letter vs. a packing slip
Spatiality	a transcript of speech vs. a diagram depicting concept relationships
Associativity	notes from class vs. doodling
Linearity	chronological notes vs. notes placed in a spatial ordering scheme
Originality	an essay vs. feedback on a manuscript
Prescriptivity	a signature vs. general notes
Finality	a document that will be archival vs. one that is a draft
Structure	a grocery list vs. concepts from a brainstorm
Personality	a letter to someone vs. a journalistic essay
Formality	a business letter vs. a greeting card to a close friend

For product development purposes, the writing acts framework can be used to ensure coverage of use

cases by generating possible scenarios combining various attributes of written documents. These potential combinations may then be explored, evaluated, and prioritized for research attention, development effort, or testing.

4.2 Possible Directions for DP Technology

4.2.1. Note taking. What would make DP technology more popular for note taking? Our research suggests that this is a complex question because there are numerous behavioral barriers. The largest single problem for DP may be that it is a closed system comprising a special pen and patterned paper and does not function with the wide array of writing utensils and paper products that people use, especially for environmentally available pens, paper, and documents. If this problem could be solved or mitigated through an expanded DP technology platform, DP would avoid the large behavioral block posed by the current need for users to change their existing pen and paper habits.

DP effectively focuses on notes as data, neglecting many aspects of the embedded social nature and process function of notes. If DP notes were easily integrated into a wider range of behavioral processes, adoption should increase. For example, if notes could be automatically handled for content such as phone numbers, appointment times, reminders, temporary content, and the like, then the DP platform would come closer to matching current pen and paper usage. However, in many cases, there is a separate and larger issue: computer technology today also is not integrated into such processes. To take a simple example, consider a written grocery list. Even if the problem could be solved to recognize, extract, and transfer the list to a PC, it would be of little use because, for most people, the PC itself is not integrated into the grocery shopping process. Much information of this kind is transient; there is no need to manage or retain it once the paper has been used.

An example of potentially closer workflow integration is shown in the recently released Livescribe Pulse Smartpen [11], which couples the Anoto DP platform with audio recording such that note takers can review the audio of a meeting or lecture at the exact point that a note was written. We believe that these kinds of additions to base DP functionality are likely to appeal to specific niches of users, but as more use cases like these are enabled over time, DP may successively attain value for larger numbers of users.

In our field trials and organizational visits, one of the most common customer expectations was that DP notes should be converted from handwriting to text; respondents commonly noted that PC data is of

little use unless it is transcribed to text. To meet customer demands, a DP product will need to address this expectation: the DP must either deliver text recognition with very high accuracy, which is a difficult problem, or it should manage the expectation in some other way that preserves customer perception of value from PC integration.

The high cost of DP products (approximately US \$100 for a pen, plus the need for specially patterned paper) poses a substantial challenge unless there is demonstrable additional benefit. Transferring notes from paper to a PC today merely involves typing. Unless the need for automation is great and the DP function is nearly perfect, users may simply prefer to type or to carry paper rather than to change behavior to use expensive and less flexible technology.

4.2.2. Structured input. As noted in the Introduction above, another use case for DP technology is structured input of information. In particular, DP technology may be useful for form-based input into database and workflow systems, where information is initially recorded on paper forms and then automatically transferred from the pen to a database application. Although the present research report is concerned primarily with note taking applications, in the course of our enterprise research we discussed potential applications for forms-based DP usage.

We noted possible use cases that fell into five general areas: (1) application of DP technology for easier input of information by customers, such as clients filling out deposit or withdrawal slips at a bank; (2) transmission of employee-generated information from paper to database without needing to rekey or type the information, such as factory inspection and quality assurance logs, traffic tickets, shipping manifests, and so forth; (3) usage in environments that were not suitable for handheld computing devices, such as construction sites and some kinds of manufacturing facilities; (4) situations in which paper-based records are desirable for either employee compliance or customer comfort, such as medical settings; and (5) situations where paper-based records are necessary, e.g., for legal reasons, but a DP product could support faster turnaround and error correction. An example of such application involved financial forms that undergo offsite optical character recognition; a DP system might allow immediate recognition and error correction.

We plan to report this line of research fully in the future. For now, we note that each of those areas has various benefits and potential limitations with regard to DP technology. Forms-based use cases are more precisely defined and structured than note taking, in terms of environment, workflow, and content; the information context, form design, and potential for

systems integration with rapid feedback may mitigate issues with handwriting recognition; and enterprise customers may be less price sensitive than consumers. Thus, structured input appears to be a more promising near-future application of DP technology than note taking.

4.3 Research Discussion

As we noted above, the present research was primarily behavioral and qualitative. Thus, despite the strength and consistency of our results across multiple samples, contexts, and locations, we present no specific metrics or tested hypotheses on user behavior with DP products. Our findings could be used to inform directional hypotheses for future depth or quantitative research. For instance, one might formulate and test hypotheses about cultural differences, interest levels in DP between various groups such as professional and non-professional office workers, market research metrics such as price sensitivity, and the like.

It is important to underscore the value of ethnographic fieldwork in the present research. It would be possible to conduct design research that explores *how* to make DP technology better, e.g., in terms of usability and function, without investigating exactly *what* people would do with such products and *why*. It was only when we investigated behavior in depth that we discovered the divergence of DP products' limited current value for note taking, as opposed to the high value that one might presume in the absence of depth research.

5. Conclusion

In our research, initial trials of digital pens in a controlled setting (Research Series 2 above) suggested potentially good fit between digital pen functionality and consumer note taking needs. However, when we explored real world behavior in note taking (Research Series 1, 3, and 4 above), we found many potential barriers to adoption of digital pens for note taking. In particular, traditional pen and paper offer advantages in terms of cost, widespread and ad hoc availability, flexibility to work with multiple sources seamlessly, behavioral workflow integration, and manageability of content.

The value of using digital pens will increase if manufacturers are able to expand their platform technology progressively to enable broader coverage of behavioral scenarios and habits, focusing on the broad range of writing behaviors rather than just needs for facsimile replication on a computer. Alternatively, digital pen technology may be more

easily applied to tasks involving structured input, rather than unstructured note taking.

We suggest that DP development efforts should use existing linguistic frameworks (e.g., [2]) to define the space of writing acts of interest. This should allow DP products to target behavioral needs in a more focused manner, leading to higher customer adoption.

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