Papyrus - Design and Evaluation of a Dual Display Notebook PC Form Factor enabling Writing/Annotation and Parallel Tasking

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Keyword(s):
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Abstract:
In this paper, we present Papyrus, a dual-display form factor for a notebook PC, featuring a large touch-screen display mounted in place of the track-pad. The new form factor is motivated by the abundant evidence in support of multiple displays for performing a variety of everyday tasks, and the need to support seamless switching between typing on the one hand, and writing and annotation on the other. We describe salient aspects of the design of this dualdisplay notebook and some specific interactions we designed to support common tasks. We also present the results of a large user study that was conducted to understand the subjective preferences between a conventional notebook and Papyrus. The results indicate that the new form factor is preferred by the users within the task conditions. We also discuss some interesting insights about the challenges of designing interactions for such form factors for e.g. cursor switching between discontinuous display surfaces.

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Blind review

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Keywords

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ACM Classification Keywords

H.5.2 User interfaces: Input devices and strategies,
K.8 personal computing, Hardware

INTRODUCTION

Over the past decade, notebook computers have been gaining rapidly in popularity and market share, and have long overtaken desktop PCs as the preferred form factor for personal computers. By 2011, IDC expects notebooks to represent 66 percent of corporate purchases, with 71 percent of consumers opting for a notebook instead of a tower [1]. Initially positioned more as a productivity enhancement tool for mobile professionals, they are now being adopted by almost all categories of users [2].

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Missing affordances

Despite their widespread use and penetration, there are certain key affordances that notebook PCs still do not provide. Important among these is the ability to write and draw. Users prefer paper to computers not only for reading, but also for annotating documents, writing notes, scribbles, drawing simple figures and so on -- affordances that notebook computers still do not support well [3,4].

There are commercially available tablet notebooks that enable users to write, draw and so on. Users need and prefer to type for various activities, as reflected in the relative popularity of convertible and hybrid tablet PCs. While these models do enable both stylus based input as well as keyboard based input, users need to explicitly choose between them, and physically twist and flip the screen as needed. We believe that this model is not conducive for tasks that might require frequent switching between the two input modes, such as the creation of content that includes typed as well as written/ drawn content.

Importance of parallel tasks

Another finding that relates to our work is the importance of multi-tasking. Users typically perform many tasks in parallel, whether at home or at work [5, 6, 7]. Modern operating systems support this need by letting users simultaneously open many task panes, each independent of the others. While the number of tasks users can do on the computer has increased, the physical size of the display has largely remained the same. The desktop metaphor too has changed little in spite of research that highlights its inadequacy in supporting multi tasking [14]. This has inspired researchers to look for alternative interaction models [5, 8, 9, 10, 11].

While such models can help in better utilization of available display space, multiple displays also aid multi-tasking [12]. Studies indicate that adding an extra monitor can boost productivity by 20 percent to 30 percent [13]. Traditionally popular with workers in the financial and the graphics industry it is now commonplace to find them even in other kinds of offices [14].

Integrating pen input, dual displays and mobility

Papyrus, the notebook form factor concept described in this paper, is inspired by three identified needs and affordances: (i) seamless switching between typing and writing/ scribbling modes, (ii) multiple displays to allow multi tasking (iii) portable notebook form factor. With its alternate notebook form factor, we believe that Papyrus provides an interesting integration of these attributes.

Our work builds on research done by Morris et al. in 2007 [15] on active reading using digital display surfaces. The study concludes with design recommendations for a hybrid system that would combine the strengths of vertical, horizontal and reconfigurable surfaces, and allow the user to easily move digital documents between the horizontal and vertical surfaces depending on whether they were being read, annotated or composed. Their work also highlights the importance for being able to enter text through a keyboard while supporting stylus input. We believe that Papyrus is a form factor that addresses many of the issues, and satisfies many of the design recommendations, identified in the study.

This paper is organized as follows. We first introduce the Papyrus form factor and the primary usage scenarios it enables. Next, we survey related dual screen form factors – both commercially available and research prototypes. This is followed by a description of the high fidelity prototype we built, and the constituent hardware and software. We then discuss the design of Papyrus prototype and discuss some key design issues and interactions. We then describe the user study we conducted to test our hypotheses regarding the proposed form factor against a conventional notebook. We conclude with a discussion of the results and other insights obtained during the process of design and evaluation, and directions for future work.

PAPYRUS

The Papyrus concept is at its core, a notebook-like device that allows stylus input in addition to providing a secondary display. This may be achieved by replacing the track-pad in a traditional notebook with a touch screen display. The touch-screen not only works as a touch-pad, it also provides a surface that users can use to write or draw, and acts as a secondary display. Figure 1 shows the envisioned design.

Figure 1. Papyrus concept visualization

Usage

The usage scenarios that the new form factor affords can be broadly divided into two categories: those related to touch and stylus entry, and those that benefit from the second display.

Usage related to touch and stylus entry

With the availability of a touch- as well as stylus-sensitive surface, users can insert annotations or drawings within documents. They can also choose to take handwritten notes. With the writing surface always accessible on the same plane as the keyboard, users can switch between typing and scribbling/drawing rapidly (Figure 2 & 3). In addition, the touch sensitivity enables users to use their fingertips to interact with interface controls.

Figure 2. Scenario of writing on Papyrus touch screen

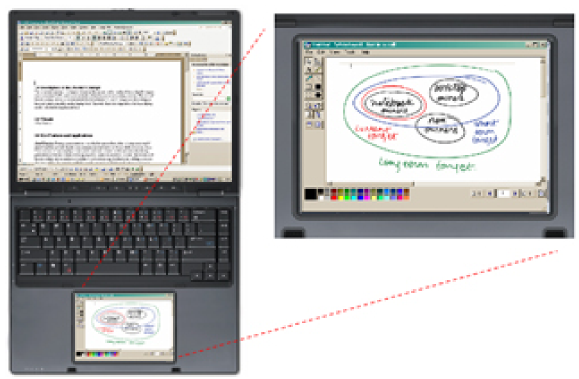

Figure 3. Depiction of inserting annotations/drawings in a document

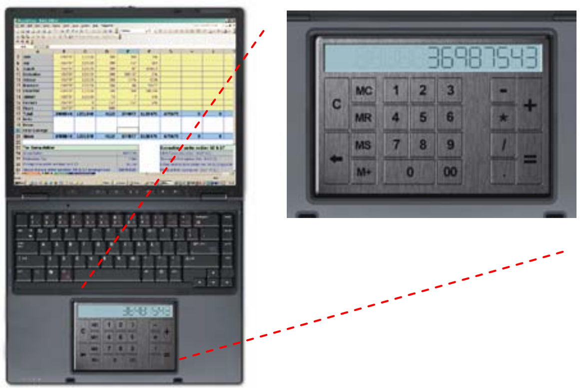

Figure 4. Example of using multiple applications simultaneously such as spreadsheet and calculator

Usage related to the second display

The second display can be used while multitasking to allow the user to constantly keep track of two applications. It is also helpful when other files need to be referred to while working on documents or spreadsheets. Figure 4 shows a typical scenario involving simultaneous use of a spreadsheet and a calculator.

Other aspects of use

The Papyrus form factor as envisioned also serves other purposes. The location of the second display makes it difficult for onlookers to glimpse the contents. By using this display for sensitive information such as accessing bank account information, Papyrus provides a measure of privacy to the user, especially in aircrafts and public places.

The fact that the second screen is smaller also means that it consumes less power. This can in turn be leveraged in situations when the user has limited access to power, by switching off the large main display and just keeping the small display on.

RELATED FORM FACTORS

There are a number of form factors that use two or more displays. These include peripheral displays and multiple monitor systems, dual display notebooks, gaming consoles, enhanced keyboards and e-book readers. We discuss some of these briefly below.

Peripheral displays and multiple monitor systems

Peripheral displays are displays that reside in the user's environment within the periphery of the user's attention and are used primarily to maintain information awareness. They have attracted considerable research both in terms of form factors [16] as well as information visualization [17, 18]. While the additional screen in our form factor can be utilized as a peripheral display we believe that it's also has the potential of working like an extension of the existing display. Work by Grudin [19] notes the advantages of multiple monitor use, some of which we feel can be addressed by our proposed form factor.

Figure 5. Dual screen laptops and Nintendo DS

Dual display notebooks

Notebook with dual displays have recently been launched [20, 21] that feature a secondary display integrated on the cover (Figure. 5). The purpose of this display is to let the user access key information such as e-mails or notes, photos, music, "mini-games" and other gadgets without having to open or boot the notebook. While the second display does benefit the user by enabling quick, low power access to the notebook, it does not address any of the issues that we have identified.

Dual display gaming consoles

Dual screens were introduced in hand held videogames as early as 1982 [22]. A recent instantiation, the Nintendo DS (Figure 5) is designed to accept input from the included stylus, the user's fingers, or a curved plastic tab attached to the optional wrist strap. The touch-screen allows users to interact with in-game elements more directly than by pressing buttons. This configuration is similar to our concept except it has been applied to a gaming device.

Dual Display E-book readers

Ethnographic studies have indicated that a large proportion of reading activities involves the use of multiple display surfaces, and concepts have been shown by Toshiba and others. Chen, et al. [24] describes another such concept and interaction techniques that might be useful on such devices. See Figure 6

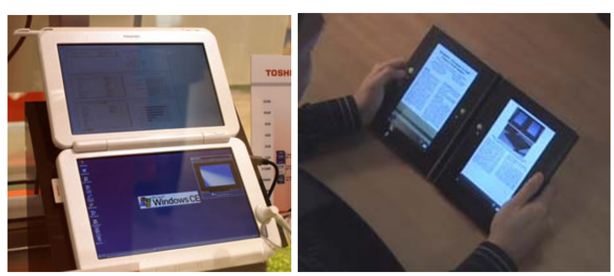

Figure 6. Dual display e-readers from Toshiba, concept described in Chen et al [24]

Figure 7. Enhanced Keyboards

Enhanced keyboards

There are example of keyboards that have been enhanced to provide an additional display and stylus input. One example from Electronic keyboard Inc. [23] which features a split keyboard is shown in Figure 7. While targeted as a desktop PC peripheral, these represent an alternative form factor for the affordances supported by Papyrus.

PROTOTYPING PAPYRUS

In order to test the new form factor with people while optimizing our resources, we had to design a prototype that would enable the key tasks that were the key differentiators. There were two components to the prototyping, the hardware and the software.

Hardware

In order to simulate the hardware characteristics of the proposed form factor we chose to fabricate a case that would sit on top of the conventional notebook keyboard surface, see Figure 8. Figure 9 represents the configuration. We selected the HP Compaq nx9010 model notebook for this purpose.

Inside the case we mounted a compact external keyboard (this was the external keyboard locally available that came closest to the dimensions of a 15 inch notebook keyboard) and a 7 inch diagonal resistive touch screen (eGalax). The touch-screen had a screen resolution of 640 x 480.

A controller that was driving the touch screen was also mounted within the box. The touch screen received power from a power supply that was kept outside this box within a separate module. The display signals to the touch screen came from the external VGA port. The touch screen was connected to one of the USB ports on the notebook, and the keyboard was connected to the other USB port.

Software

The software that was designed specifically for the experiment had three main components (i) Driver component that was responsible for the absolute to relative coordinate conversion and setting the mouse speed on the Primary display. (ii) Cursor control module restricted the cursor movement within the corresponding screen and enabled the user to toggle the cursor between the two screens. (iii) Windows application display toggle module enabled the use to toggle the application window between the two screens.

DESIGN RELATED ISSUES

Touch screen size

Several factors influenced the size of the touch-screen. The most popular notebook size at the time of the design exploration was the one with the 15 inch display, hence this size of notebook was selected as the basis for our design. The touch-screen display had to be large enough so that its contents would be readable and reasonably clear, and yet not so large that it encroached upon the resting area for the user's palms. After the modification and the relocation of the keyboard, the maximum size of display we could accommodate was a seven-inch diagonal.

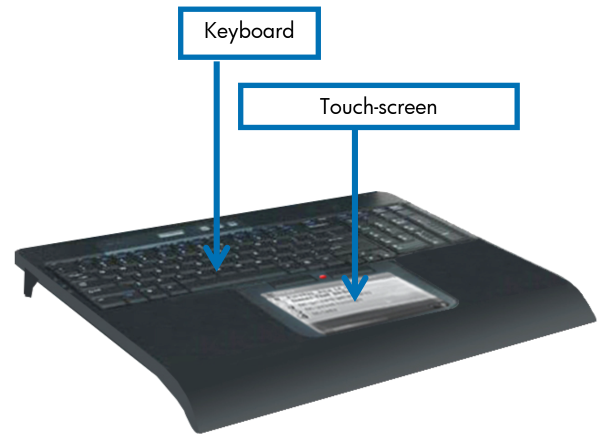

Figure 8. Displays the Papyrus prototype with a keyboard and a resistive touch screen for display and mouse control

Figure 10. Papyrus prototype placed on a conventional notebook to give the papyrus form factor

Location of the touch screen

In order to accommodate a touch screen bigger than a standard track pad, we modified and shifted the keyboard towards the screen. The function row of keys was removed and the same functionality was provided by adding another toggle key through which users would be able to use the number keys for accessing the function controls. The touch-screen was placed in the bottom band in the center of the keyboard bed. While track-pads in most notebooks are not centered exactly, given the much larger size of our touch-screen, we placed the screen in the center for the first iteration. The screen was placed below the keyboard to avoid accidental key presses when the user was trying to interact with the touch screen.

Track pad and toggle of cursor control- mouse click

Because the track-pad was replaced with the touch screen, the overall cursor control of the system presented interesting challenges. The touch screen was the single interface through which the cursor had to be controlled for the top screen (primary display) as well as the secondary screen (touch-screen added to the keyboard bed). As the same input mechanism was being used to two controls, there was a need for a toggle that let the users switch between cursor control on the primary display and the secondary screen. The toggle mechanism proposed for the prototype was a function key (F4).

After initial trials we discovered that it was difficult to locate the cursor on the screen. With two screens the users had to look across both screens to locate the cursor. Users also typically located the cursor by moving it across the screen. Since the input device itself could be toggled between the screens, the task of spotting the cursor became too cumbersome for users. In order to resolve this, we assigned another function key (F6) that would highlight the location of the cursor with blinking concentric red circles.

Conventionally track pads are relative cursor control devices and touch screens are absolute cursor control devices. We kept to these conventions while prototyping the device. When the touch screen input was used for the primary display it worked in relative mode just like a touchpad; when the toggle key was pressed, the cursor control switched into the absolute mode.

As mentioned above, the cursor control presented several challenges. While addressing these issues we case across work by Benko et all [25] on techniques to toggle cursor control between screens and work by Baudisch et all [26] around mouse movement across screens. While relevant it is difficult to apply their findings to our work because in our case the touch-screen itself is being used for cursor control on both the displays. While work by Sears and Shneiderman [27], Meyer et all [28] throw light on performance of relative and absolute cursor control mappings our cursor control system limited the direct applicability of their research. While we feel a need of research in this area specific to our kind of cursor control environment.

Touch screen resolution

In our prototype, we treated the touch screen as a secondary monitor specified as part of the display properties in Windows XP. Since the physical size of the secondary screen (touch screen) was smaller, we required the content to adjust its graphic size to make sure it was legible. Some applications have mechanisms that enable this, but the only way to increase the size across applications within the Windows framework is by reducing the resolution. While this solved the issue of the physical size of the graphics on the display, it also reduced the sharpness of the graphics. Although we managed with these compromises, this area requires additional research from the display architecture and the Human Factors perspective.

Specialized interaction techniques

As described earlier, the Papyrus form factor opens up the possibilities of new usage scenarios. While we expect many more other unconventional usage scenarios to be possible with the new form factor, we chose to incorporate two interaction techniques that directly supported our hypotheses regarding the need for writing and that of a second display.

Single click copy & paste

One of the usage scenarios that we wished to enable was to let the users insert drawings or doodles within their note-taking applications. Most applications that we use today have been designed for a single screen operation. Word processing applications do permit users to do this but they open drawing interfaces within the document within which the drawings are directed. In order to enable this scenario, we enabled a command that would “select all” within Microsoft Paint, “copy” the content, and “paste” it within Microsoft Word. A user working on a Microsoft Word document on the primary screen could seamlessly switch to drawing using MS Paint on the secondary screen. When done, one key press would copy his or her drawing from MS Paint and paste in within the document on the primary display.

Single key toggle for the moving the application user interface between displays

With two displays, the user has the choice of deciding the display to which to direct an application interface. Some of this user choice can be supplemented with system intelligence that allows the system to learn user preferences regarding which display to use for a specific application. For instance, users may always want to use MS Paint or Calculator on the secondary display. For the purposes of our prototype, and since we were only dealing with two displays, we mapped a basic toggle control to the F8 key. When F8 was pressed, the application window in focus would automatically get transferred to the other screen.

EXPERIMENT DESIGN

The goal of our user preference study was to compare the Papyrus with a standard notebook within specific representative task conditions completed by the same users. We wanted to understand the users' preferences towards the two device forms factors. In addition, we wanted to understand if the ability to write and draw added value to the existing form factor and to assess whether the extra display was perceived to aid in typical user tasks. Another objective was to inform future research decisions with evidence from statistical analysis. The decision of comparing Papyrus with a standard notebook and not a Tablet PC was based on the overwhelming popularity of standard notebook computers.

Two hundred people and one were recruited within our office premises for the study. The sample size was set at the level that would afford sufficient statistical basis for detecting differences between user ratings of each form factor. All the participants were professionals in various job functions varying from marketing to administration. All the participants were active users of computers. The sampling process randomly selected participants from within subgroups based on job function, education level, age and gender. None of the participants were programmers or people whose work involved programming of any sort as their computer usage is significantly different from mainstream business users. Participants were rewarded with gift coupons at the end of the study. Each participant spent about 90 minutes in the experiment. Of the total 201 participants 125 were male and 76 female.

Within the experiment session, each participant was given an introduction to the study followed by an introduction to Papyrus. This was followed by a training video that explained the key value and the functionality of the prototype. Users were given a few minutes to practice what they had observed in the video, and then the actual tasks were carried out. There were five tasks total, three involving hands-on usage, and two involving responding to videos of other people doing the tasks. Each of the tasks was repeated on the conventional notebook as well as on Papyrus. After completing the task on the specified form factor (i.e., the notebook or the Papyrus), participants were asked to complete a questionnaire about their experiences. Once they had completed the same task on both the devices, they completed another questionnaire that asked them to assess how realistic and frequent the task was, as well as their preference of the form factor for that specific task. The order of presentation of the three tasks as well as the form factor introduced within them was systematically varied across participants to balance order effects.

Tasks

The tasks selected for the experiment were based on two primary criteria. The first criterion was that the task should be representative, i.e., it should be something that was realistic and was likely to be performed often by them at their work places. The second criterion was that the task should be one that benefits from the new affordances of Papyrus. We divided the five tasks into two categories: tasks that involved writing, drawing or some form of handwritten entry, and tasks that required the user to refer to or use another application window in parallel. A set of tasks was generated by the core team of design researchers, business analysts and technical researchers, who brainstormed a large list of possible tasks. These tasks were then discussed and piloted with a smaller sample of fifteen users after which the final tasks were chosen and detailed. Because participants came from various job functions, their daily activities and tools differed greatly, so it was also important for the tasks to be as generic as possible while also being detailed enough to be realistic.

Task A- Reviewing a document

In this task, the participant received an email with an attachment. The text in the email requested the participant to review the attached document and suggested changes to the formatting. This task of reviewing a document and making changes usually requires annotations. The hypothesis was that through stylus entry the user would be able to annotate documents just as s/he would on paper, and would thus prefer the Papyrus. [15]

Task B- Drawing small sketches/ diagrams

This task simulated a situation in which the user was listening to a presentation and taking notes. In the presentation, there comes a slide that has a simple diagram. The participant was asked try to record that slide within his/her notes to take it back to colleagues. We chose this task because simple diagrams are a part of all kinds of communications within offices. Whether it is a discussion, meeting or presentation, visuals play an important role in communicating concepts. Although the textual part of the discussions is usually captured in notes, the illustrative visuals are seldom electronically captured. This task recreated the situation, and the users were made to take notes of the presentation with an illustrative diagram on both the form factors.

Task C- Referring to a document

In this task, the participant received an email about an offer from a website. The email also contained instructions for the steps to be taken on the web page. The user is asked to simply follow the instructions. Through this task, we wanted to recreate a situation where other application windows need to be referred to while working on an application. The assumption was that the users would need to switch back and forth between the windows to complete the task, something that wouldn't be necessary in case of two displays.

After the users had finished the above three tasks they were shown videos of two more tasks being carried out on each of the form factors. They were then asked to imagine themselves in the same situation and then rate the performance of the form factors.

Task D- Making a quick note (Simulated video)
The participants were shown a video of a situation when a user is working on a laptop and receives a phone call. During the conversation he is given some details that he needs to quickly jot down. In the version using a conventional notebook computer, the user takes down the details on Notepad. On the Papyrus version of the task, the user uses the stylus to write them down on the second screen. This is where the second touch screen display could bring value by providing an extra writing surface for small notes, scribbles etc.

Task E- Referring to slide notes (Simulated video)
The participants were shown a video of a user giving a presentation. During the presentation he refers to his notes. In the version with the conventional notebook computer, the user refers to a hardcopy of the notes. In the version of the video with Papyrus, the user refers to the notes which appear on the second screen. Presentations are now used regularly in most offices. Often there is a need to keep some notes about the presentation at hand in case they are needed for the specifics. People address this in many ways --- by bringing printouts, writing notes in a paper notebook, or by keeping them in the notes section of the presentation. The second screen would be useful in such situations, letting the user select one screen to display the presentation and the other to display the slide notes.

Setup (figure 11)
The conventional notebook computer and Papyrus were kept side by side on a table see figure 10. There was another computer in the background that was used for screening the videos. Both the notebooks were running Windows XP. Microsoft Word, Excel, Outlook, Powerpoint, Paint and Onenote (Microsoft office 2003) were used for the different tasks.

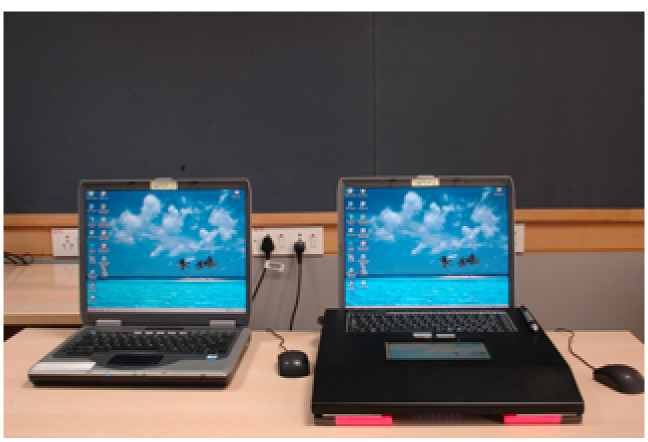

Figure 10. Notebook PC and Papyrus side by side

Figure 11. Test setup with moderator and participants

DESIGN OF EVALUATION

The following categories of data were collected from the participants in the study:

- Demographic data, such as years of work experience software use, time/location of internet access, income level, etc.
- Preference ratings on the experience of each form factor within each task
- Preference ratings across form factors within each task
- Feedback on the overall experience during the experiment

Demographic and computer usage habits
The demographic questionnaire captured information about the gender, age and the job profile of the participants, as well as a variety of questions about their computer usage. This included information about whether they used a notebook computer at work and if so, for how long and how much. Data related to mouse and keyboard usage was also captured, as well as usage frequency of applications, primarily those included in the Microsoft Office suite.

Preference ratings on the experience of each form factor within each usage task
Once the participants had finished a task on each form factor they were asked to complete a short rating questionnaire. These questions covered ease of use, satisfaction, comfort, how well could they express themselves and their overall experience. A rating scale from 1 to 7 was used for each question, where 1 was strongly disagree and 7 was strongly agree.

Preference ratings across form factors within each task
After the participants finished the same task on both form factors, they were asked to rate their experience across the two task conditions. They rated how realistic the task was, how frequently they encountered a similar situation in their work, and the extent to which they preferred one or the other form factors for that particular task.

Feedback on the overall experience during the experiment

At the end of all the task conditions, participants were asked how often they saw themselves using the Papyrus functionality, preference for screen size, importance of storing handwritten notes electronically, and a series of head-to-head comparisons of the two form factors.

RESULTS

Overall preference

The average preference rating across all five scenarios for the Papyrus form factor was significantly higher than the average rating for the conventional notebook form factor. The different in average preference ratings was statistically significant (see Table 1). The average preference rating was calculated based on ratings by participants while completing each task using one of the form factors (responding to a statement such as "I found this laptop useful for this activity"). The rating was made on a seven point scale where 1=strongly agree, 4=neither agree nor disagree and 7= strongly agree. The average rating during the Papyrus condition corresponded to "Agree" compared to the average rating for the conventional notebook, which corresponded to "Neither agree nor disagree."

Head –to-head preference

The ratings after each task comparing both form factors head-to-head also strongly favored Papyrus. The average rating was 6.1 on a seven point scale where 1=Strongly prefer the conventional notebook; 4= No difference between the two form factors; 7=Strongly prefer Papyrus.

Preference across dimensions of user experience

The data revealed several interesting differences across the dimensions of user experience. These were the dimensions rated during each task using each of the form factors. In particular, three dimensions – likeability, usefulness and ability to express oneself – showed a greater preference for Papyrus. We concluded that the Papyrus functionality would have a greater impact for users on these dimensions of user experience. (See Table 2)

Ratings of each notebook by task (n=201)			
	Conventional Notebook Mean(SD)	Papyrus Mean(SD)	t (p-value) *** p<.0001
Task A- Reviewing document	4.9 (1.4)	6.1 (1.0)	10.6 ***
Task B- Draw diagram	3.9 (1.5)	5.8 (.83)	17.0 ***
Task C- Refer document	5.2 (1.4)	6.1 (.85)	9.1 ***
Task D- Quick note	3.8 (1.4)	6.2 (.85)	21.3 ***
Task E- Presentation notes	4.0 (1.3)	6.3 (.77)	22.8 ***
Average across tasks	4.3 (1.0)	6.1 (.65)	23.9 ***

Table 1. Overall preference ratings

Ratings of each notebook across tasks			
	Conventional Notebook Mean(SD)	Papyrus Mean(SD)	t (p-value) *** p<.0001
Natural	4.6 (1.0)	6.1 (0.6)	21.2 ***
Comfortable	4.5 (1.0)	6.1 (0.6)	19.2 ***
Easy	4.4 (1.0)	6.2 (0.6)	22.2 ***
Liked	4.2 (1.0)	6.2 (0.7)	22.4 ***
Useful	4.3 (1.1)	6.3 (0.6)	23.6 ***
Could express myself	4.1 (1.1)	6.2 (0.6)	24.2 ***
Overall Experience	4.4 (1.0)	6.3 (0.6)	22.8 ***

Table 2. Preference across dimensions of user experience

Preference comparisons by gender

When we took the participant's gender into account, we found no statistically significant differences between male and female users, though there were some indications that the females had a stronger preference for Papyrus.

Preference comparison by job function

There were four categories within job functions: Marketing & Sales, Human Resource & Administration, Finance and Operations, and Others. The results indicated a statistically significant lower preference for Papyrus among participants in the Marketing & Sales function when compared head-to-head with the conventional notebook.

Preference comparisons by user computing characteristics

No differences were found in the preference results between laptop and desktop users. However, there was a trend towards higher preference for Papyrus in non-notebook users when making a head-to-head comparison. There were no statistically significant differences in preference ratings corresponding to participants' years of laptop usage (though there was a trend towards greater preference in newer laptop users). There were also no statistically significant differences in ratings by users with different levels of typing proficiency.

Not surprisingly, we did find a statistically significant preference for Papyrus for participants who indicated that they would like to be able to store their notes electronically, compared to those who did not think they needed to. When asked about how often they would use the Papyrus technology if they owned it, 88% responded that they would use it frequently.

Ratings of each notebook by task (n=201)		
	% who say task is realistic	% who encounter task once/wk or more
Task A- Reviewing document	98%	83%
Task B- Draw diagram	96%	72%
Task C- Refer document	97%	90%
Task D- Quick note	98%	98%
Task E- Presentation notes	94%	63%
Average across tasks	97%	81%

Table 3. Ratings of realism and frequency of experimental tasks

Ratings of realism and frequency of experimental tasks

The users were asked at the end of each of the five tasks about how realistic they found the task to be and how often they experienced such situations in their work. Across tasks, 97% of the participants indicated that the tasks were realistic and 88% indicated that the task situations occurred at least once a week in their work. See Table 3.

DISCUSSION & FUTURE WORK

Our study indicated user preference for Papyrus over the conventional notebook computer within the given task conditions. The results also indicated that both key features - handwriting input and additional display – were valued equally by users.

There remain a number of open questions regarding the new form factor, such as the long term impact of the user preference, usage of the touch screen as a track pad, ease of writing on a seven inch screen, interference with typing, and ergonomic fallouts, which can only be answered with additional specific and longitudinal studies.

During the course of the design exploration and user evaluation, many interesting interface and interaction research issues were identified but not addressed. Some of them were:

Cursor control: There are several challenges within this area. How does the user toggle the output of the touch-screen so that s/he can control between the touch-screen itself and the main display of the notebook? How can the user be informed of the location of the cursor?

Active window: What is the best way to inform the user of the active window and/or display? What happens when one of the displays is turned off? How are the windows ordered and how can the users switch between them?

User interface: The Windows interface has been designed for a single display system. How should the interface be redesigned to exploit the dual display setup? How would applications utilize this kind of configuration? For e.g. can the task bars and the buttons be shifted to the touch screen ?

Resolution and physical size: What is the optimal resolution for the smaller screen? How can the displays on the larger displays be mapped onto this smaller display intelligently?

Touch-screen technology: We chose resistive technology as it fit the scope of our experiment. The ideal touch screen technology needs to be very carefully chosen. The issues that it should address are: support finger and stylus touch, should have robust palm rejection and should have the right tactile feel (should be smooth but also provide some friction for writing but should not feel sticky).

Application support: There is a need for applications that support seamless shifting between stylus input and keyboard input. Most applications require some explicit actions before the user can switch between the two modes since the two inputs are not integrated in their interface.

The wealth of research issues is merely an indication that the entire space of designing interfaces and interactions for devices with dual or multiple displays is still in its infancy, and much research lies ahead. Further, designing for devices that use a primary and secondary display with different affordances, as opposed to two identical ones, brings forth a different set of issues.

CONCLUSIONS

In spite of the ubiquity of pen and paper, handwriting input in the form of writing, drawing, scribbles and annotation is not a key affordance of notebook computers. Those computers that support handwriting input often do not provide seamless interfaces for typing as well as writing. Papyrus, the notebook-like form factor we propose, enables these affordances, and in addition provides a secondary display to support multi tasking. The use of a primary and secondary display raises a number of interesting design issues related to the ergonomics, interface and interaction, some of which we have addressed. We have tested our hypothesis regarding the proposed form factor against a conventional notebook in a large user study involving 201 users, to understand if the ability to write and draw added value to the existing form factor and to assess whether the extra display was perceived to aid in typical user tasks. The results show a statistically significant preference for Papyrus over the conventional notebook form factor for the selected tasks. We believe that this research effort has just scratched the surface of what is possible in terms of new form factors, especially those featuring heterogeneous display surfaces, and much research lies ahead.

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