Paper vs. Tablets: The Effect of Document Media in Co-located Collaborative Work

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ABSTRACT

With new computer technologies portable devices are rapidly approaching the dimensions and characteristics of traditional pen and paper-based tools. Text and graphic documents are now commonly viewed using small tablet computers. We conducted a study with small groups of participants to better understand how paper-based text and graphics are used by small collaborative groups as compared to how these groups make use of documents presented on a digital tablet with digital styluses. Our results indicate that digital tools, as compared to paper tools, can affect the levels of verbal communication and participant gaze engagement with other group members. Additionally, we observed how participants spatially arranged paper-based and digital tools during collaborative group activities, how often they switched from digital to paper, and how they still prefer paper overall.

Categories and Subject Descriptors

H.5.3 [**Group and Organization Interfaces**]: CSCW

General Terms

Human Factors; Design; Measurement;

Keywords

Paper; Digital Tablets; Group Work; Hybrid Interfaces

1. INTRODUCTION

The popularization of tablets and e-book readers is rapidly changing how text and documents are being consumed; Amazon reported in 2012 that their sales of e-books had overtaken the sales of paper books for the first time [21]. Part of this shift from paper-based text delivery to digital devices can be attributed to the advances in reading hardware (e.g., resolution, brightness) and the increased familiarity of the public with mobile devices. Modern-day reading devices are lighter, brighter, interactive, and widespread.

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Although most of these are currently still personal devices used individually for personal reading, it is likely that the replacement of paper will also spread to most other current uses of paper, including co-located collaborative work. We are not the first in imagining a future in which groups of people collaboratively manage multiple dynamic digital devices to accomplish intellectual tasks [35].

However, Sellen and Harper taught us that, despite the inherent advantages of digital media, it is costly to blindly assume the superiority of digital documents over physical paper. Multiple studies summarized in *The Myth of the Paperless Office* [31] found subtle ways in which paper was a better medium, in particular for collaborative tasks. They conclude *"The design of digital tools may eventually be capable of supporting these knowledge work activities much better than they currently do [...] if designers look to paper use for guidance"*, yet there is a conspicuous lack of comparisons between paper and digital technologies in recent HCI work.

The current acceptance of digital devices and the improvements in technology have changed much of how text and documents are accessed since 2001. However, we still need a good understanding of how paper compares to current technology in order to design better technological support for co-located collaborative tasks.

In this paper, we present a study of small groups of people performing collaborative analytical tasks using traditional pen and paper, using pen and touch-enabled tablets, and using a combination of both. This study is the first to observe semi-controlled analytical tasks that compares these three conditions. Participants were also able to use more than one device per person, which allows us to explore the use of tablets as notebook or paper substitutes rather than as singular personal devices.

A quantitative and qualitative analysis of the video data recorded during our study revealed that interaction between group partners is affected by the use of digital technology. When given only digital tablets for use participants spent more time looking at the digital tool than interacting with other group members.

2. RELATED WORK

Early relevant work are the series of studies by Sellen, Harper, and their collaborators summarized in [31], which itself follows an explosion of work on co-located collaborative environments in the late 1980s/90s (e.g., [14]). However, the landscape of digital tablet ownership has changed greatly since the publication of [31]. In September 2010 4% of American adults owned tablets, by 2012 that number stood near

25% [27]. Tablets sales are expected to overtake PC sales by 2015 [3]. This change in ownership of tablets is likely to also affect the attitudes and usage of these devices for co-located collaborative work activities that are still mostly accomplished with traditional non-digital tools.

Previous research relevant to paper usage in groups is that of Tang, who observed patterns on table-based collaborative activity [34] and Kruger et al., who examined the role of orientation in the use of paper in collaborative activities [19].

Research in the area of co-located collaborative work has focused on exploring and understanding novel digital tools for collaborative activities (e.g., [17, 35, 28, 24, 23, 6]), and the creation of new ways to interact with hybrid digital/paper tools (e.g., [36, 15, 32]). Multiple groups have also analyzed how digital tools affect collaboration by looking at input [12], interaction techniques and embodiment [26, 25], the number of devices [13], and different types of shareable technologies [16, 29]. Interestingly, their findings indicate that subtle changes in the technology can affect key indicators of the quality of collaboration such as workspace awareness and participation equality, and that sometimes the use of more devices (instead of a single digital device) can result in a degradation of task outcomes [29].

Of particular interest is the work of Wallace, Scott, and MacGregor [35] who investigated how a digital tabletop, digital tablets, and both together supported collaborative sense making tasks. The key difference between their work and our investigation is the use of real world paper documents on a standard tabletop as compared to a digital table top with representations of paper documents.

There also exist some studies comparing digital to non-digital tools, although those typically focus on specialized contexts. For example, Dale and Hagen found advantages of PDAs with respect to paper to collect patient data [7], Elliot and Hearst compared digital desk and tablet affordances in architectural contexts [8], Marcu et al. analyzed the use of paper for autism education [22], Bondarenk and Janssen as well as Garfield found possible cognitive load reductions when using portable devices [4, 10].

Most similar to our work is that of Takano et al. [33] who recently compared paper, an iPad2, and a laptop, and found that people spoke more and demonstrated increased eye contact with paper. Our study differs from theirs in several fundamental ways: a) we enable multiple tablet devices per person so that digital devices can be more flexibly used, b) our tablets include styluses, enabling note taking in a similar way to paper, and c) we study triads, which represent a wider type of collaboration phenomena than pairs.

3. STUDY

To discover more about the influence of digital or paper based reading and annotation for small group collaborative tasks we conducted a study where people used three sets of tools: paper only, tablets only, and a combination of both.

3.1 Participants

Eight groups of three participants (3 female, 21 male, 30 years old in average) were recruited via electronic postings and word of mouth among the staff and students of the University of St Andrews, Scotland. People within a group were already friends or colleagues except for two of the groups, where one participant did not know the other two group members prior to start of the study.

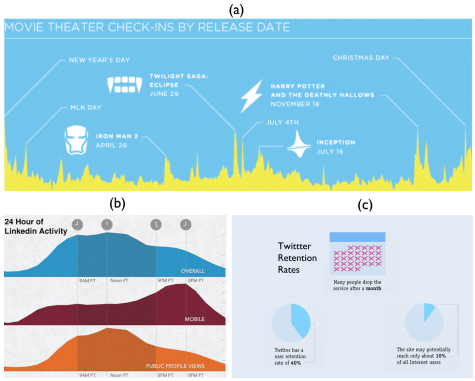

Figure 1: Example Infographics: a) FourSquare [1], b) LinkedIn [20], and c) Twitter [30].

Participants' computer and tablet experience was heterogeneous, although all self-described as at least as knowledgeable computer users. The experience level ranged from participants who used computers daily for work or study, to computer science academics. Three participants were computer science academics, two worked as office assistants, one participant was a high school student, and the remainder were comprised of a mixture of undergraduate and graduate students studying a variety of academic topics.

3.2 Task

We chose an experimental task that would allow participants to work in teams to perform collaborative analytical work without forcing particular procedures or actions. Participants assumed the role of journalists who had to write a report on a topic using six source documents (two text documents and four infographic documents). Groups had to briefly describe an agreed-upon outline of their report to the experimenter after the end of the task, which had a ten minute time limit. Groups were advised to use elements from any and all documents in their outlines, and warned that the different documents could contain contradictory information. This task resembles those in previous work such as [13, 35].

There were three possible task topics: Twitter, FourSquare, and LinkedIn. For each topic six documents were available: two were 600-800 word text documents and four were static infographics (see Fig. 1), all taken from Internet sources such as Wikipedia and about varied aspects of the topic (e.g. history, financial information, and client statistics). The texts were selected for reading difficulty by measuring with a battery of readability analysis algorithms (e.g., Flesh-Kincaid [9]) and occasionally adjusted to achieve a homogeneous level across documents of a 9th grade student.

3.3 Setting and Apparatus

The experimental room had enough space and chairs to seat a larger group, this allowed participants to stand, sit, or move freely around the space (see Fig. 2, 3). The groups were recorded by two digital video cameras, one recording the main work area from directly above, and one taking a more global view of the group from one side. A laptop on the table displayed the remaining task time.

For the paper and hybrid conditions we used standard paper in sheets of 4.5" by 7.0", printed on one side. Documents with multiple pages were stapled. The participants also had

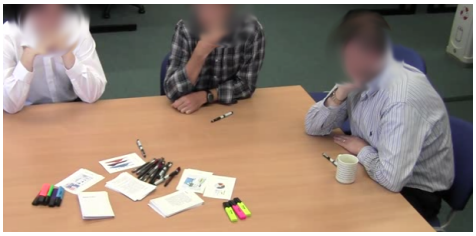

Figure 2: Initial setup for the paper-based task.

Figure 3: Initial apparatus setup for the hybrid task.

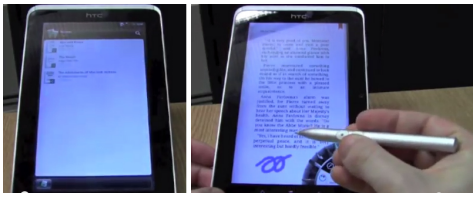

Figure 4: Document selection interface (left) and a text document with stylus annotations (right).

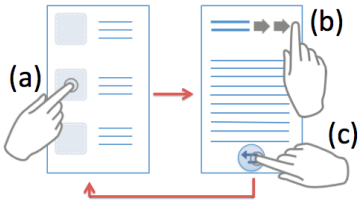

Figure 5: Document interactions within the reader application. A) Single tap opens a document, b) swiping turns pages, and c) tap on back button goes back to document menu.

plenty of blank paper bundles, and an abundance of pencils, pens, and highlighters of different colors.

For the digital and hybrid conditions the groups had eight HTC Flyer digital tablets (4.80" by 7.69" in size). These enable both touch and digital pen input, weigh 420 grams, and have screens with a wide angle visibility of 160 degrees. The tablets ran HTC's default reader software application. This software displayed a single initial screen providing access to all documents (including a blank document for notes) in a visual list displaying a small icon of the first page of the document, the document name, and the number of pages for each document (see Fig. 4). Participants could tap on the documents with finger or stylus, which opened the corresponding document in full screen view. Participants turned digital pages by dragging their finger or stylus horizontally across the screen. Pushing the "back" button of the tablet gets back to the main screen that displays all documents (see Fig. 5). Besides taking notes on the blank document, participants could also annotate any other document, on any of the tablets, with any of the digital pens.

We did not perform specific usability tests on the tablet software used during our study but did undertake a pilot study where we invited participants to provide feedback about the tablet software. Based on feedback from pilot participants we modified our tablet instructional video to demonstrate how to use the tablet devices. During our pilot study period participants did not experience or identify any major usability errors or issues that prevented them from performing their tasks.

3.4 Study Design and Conditions

The experiment followed a within-subjects design, in which each group went through the three conditions, with counterbalanced combinations of topics and conditions. Half of the groups started with the paper condition and half with the digital condition. The hybrid condition always took place last to allow participants to choose whichever tools they preferred, having already familiarized themselves with both types of tools through the previous tasks. This design also avoids possible interferences of the hybrid condition with the central comparison of the study (paper vs. digital).

At the end of each task, participants answered a post-task questionnaire consisting of Likert and open ended questions. When the questionnaire was completed by all three participants in the group the next set of tools were placed on the table and the next task commenced. After the completion of all tasks the participants filled a final questionnaire about their general tool preference.

3.4.1 Paper Condition

Before starting each task, the experimenter stacked eight copies of each paper document in the center of the table, in 6 piles (each with copies of the same document). Another pile of 8 paper notes, and 8 pens (black red and blue) and 8 highlighters (of various colors) were available on the table.

3.4.2 Digital Condition

The digital condition tried to replicate the paper condition closely; however, each tablet contained copies of all available documents and blank notes because restricting documents to specific tablets is an unnecessary constraint that is not natural to the digital format. All participants saw, previous to the digital condition, a video tutorial explaining the tablet features and the simple interface. At the beginning of the task all the tablets were located in two piles of four in the middle of the table, with the eight digital pens next to them.

3.4.3 Hybrid Condition

The hybrid condition combined the apparatus from the other two. Participants were told to use any tools with no restrictions.

4. DATA COLLECTION AND ANALYSIS

The main sources of evidence for the analysis are the 240 minutes of video (30 min per group, 10 min per condition) and the subjective questionnaires.

We specifically choose to explore the video dataset using an open coding paradigm, and to combine quantitative and qualitative analysis. First, we felt that we needed to gain familiarity with the data multiple times before we could direct our attention and effort to a few of the many possible measures. The videos were analyzed in multiple passes following a grounded theory approach [5, 18], in which the full video data set was viewed over 20 times. Initial passes were used to determine phenomena of interest; more specific subsequent passes helped develop coding schemes that were then coded for the full length of the video. The coding was performed

mostly by one author using the F5 software package. To validate the final coding we randomly chose 9 segments of 10 minute video (one segment per coding scheme per condition) which were independently coded by another author. Agreement in the measures of greater than 95 % indicates that the quantitative analysis is reliable.

The statistical analysis of coded data was based on repeated-measures ANOVAs. To avoid breaking the independence assumption of ANOVAs and t-tests we averaged the measures of individuals in a group and only analyzed group measures. When the assumption of sphericity was not held (significant Mauchly's test), the ANOVAs used Huynh-Feldt corrections, which can be identified in our results section through the non-integer degrees of freedom of the F values.

Besides statistical analysis of the video, we also collected instances of relevant behaviors that, due to the open nature of the task, are not easy to quantify or compare statistically with small samples. We report these after the quantitative analysis. Finally, we report the answers to the final questionnaires and relevant comments made by the participants in the questionnaire's comments section.

5. RESULTS

We report three kinds of results in three sections: quantitatively coded results, qualitative observations, and subjective responses.

5.1 Quantitatively Coded Results

The process of open coding described in the methodology section led to coding of multiple kinds of temporal data such as the temporal verbalization patterns, gaze location, device switching, and simultaneous device usage. Of these, the most noteworthy quantitative results come from gaze location and verbalization patterns.

5.1.1 Gaze Location

In co-located collaborative work, where people are looking can be a useful indication of whether they are effectively using visual information of others' activities to coordinate work (i.e., achieve workspace awareness [11]). We used the video to code the periods that participants spent looking at different areas. We defined four possible areas of interest: a) looking at the tool one is currently using; b) looking at the tool being used by or in the proximity of another participant, c) looking at a fellow group member or members, d) looking elsewhere. Timing was done with a granularity of 1 s and normalized to percentage of the overall trial time before analysis. One of the participants of the last group was not visible on the video due to an unusual position and, for this group, the average percentages are calculated with two rather than three participants.

A two-way repeated-measures omnibus ANOVA with device (digital, paper, hybrid) and gaze location (own tool, other's tool, other participant, elsewhere) as factors showed a main effect of gaze location ($F_{1.772,12.402} = 233.68$, $p < 0.001$, $\eta_p^2 = 0.971$) and of the interaction between device and gaze location ($F_{6,42} = 3.821$, $p = 0.004$, $\eta_p^2 = 0.353$). Since the interaction between the two factors was significant, we proceeded to analyze each gaze location for differences between device conditions.

A one-way repeated-measures ANOVA of the gaze time on *own tool* shows an effect of the device condition ($F_{2,14} = 4.208$, $p = 0.037$, $\eta_p^2 = 0.375$). The digital condition saw participants looking at their own tools for the longest (83.2 % of the total task time). This proportion was 76.4% for paper and 79.0% for hybrid. The post-hoc tests show significant differences between the digital and paper conditions ($p = 0.042$), but not between paper and hybrid or digital and hybrid ($p = 0.231$ and $p = 0.114$ respectively).

An analogous test for gaze on the *other participant* shows an effect of the device condition ($F_{2,14} = 5.222$, $p < 0.020$, $\eta_p^2 = 0.427$). Participants looked at other participants the most in the paper condition (12.8% of the task time) and the least in the digital condition (6.9%), almost half the amount of time. The hybrid condition was, again, in the middle with 10.3%. Correspondingly, the post-hoc tests show significant differences between digital and paper condition ($p = 0.018$), but not between paper and hybrid condition ($p = 0.155$) or the digital and hybrid ($p = 0.129$).

For the other two locations of gaze (the other's tool, and elsewhere), the ANOVAs were not significant; therefore, we did not perform further post-hoc tests for these.

5.1.2 Verbalization

We were interested in seeing whether groups generally talk more or less with different conditions, and whether the verbal participation balance between participants was also affected by the type of device used. We therefore coded the amount of time that each participant talked, also with a granularity of 1s. The verbalization patterns of all groups are displayed in Fig. 6. The graphical representation of the figure does not reveal any obvious patterns, or differences between conditions, other than talking usually started after a period of silence. This lack of regularity is typical of complex intellectual tasks, where individual differences play an important role in group behavior and each person needs to adapt to the group, the task, and the process of a particular trial. This result is therefore a confirmation of the adaptability of the collaborative process shown elsewhere (see, e.g., [17]). However, although the process is highly variable and heterogeneous, the quantitative analysis of the amount of verbalization did expose some differences.

A one-way repeated-measures omnibus ANOVA with device (digital, paper, hybrid) as main factor showed an effect of device on group's average verbalization time ($F_{1.332,9.323} = 4.768$, $p = 0.048$, $\eta_p^2 = 0.405$). None of the post-hoc differences were significant, but the percentages of time speaking are revealing: on average, participants spent 50.3% of the time talking to each other in paper conditions, 49.2% in the hybrid condition, and 33.5% for tablets.

We also analyzed equality of verbal participation obtaining a Gini index [2] per group and condition in a similar way to [29]; however we did not obtain a significant result ($F_{2,14} = 0.773$, $p = 0.480$, $\eta_p^2 = 0.099$). Notice that, as we discussed above, only large effects tend to show up in tests of this kind of experiment. Speech and collaboration patterns are highly adaptive, and this kind of experiment is necessarily limited in the sample size, which makes it difficult to obtain adequate power (see also the discussion in [29]).

5.2 Qualitative Observations

The multiple passes of analysis of the video information, and the notes from the experimenter allowed us to observe and label multiple instances of events and behaviors that are relevant for our research but, due to their sparseness, are not amenable to quantitative analysis. Although we do

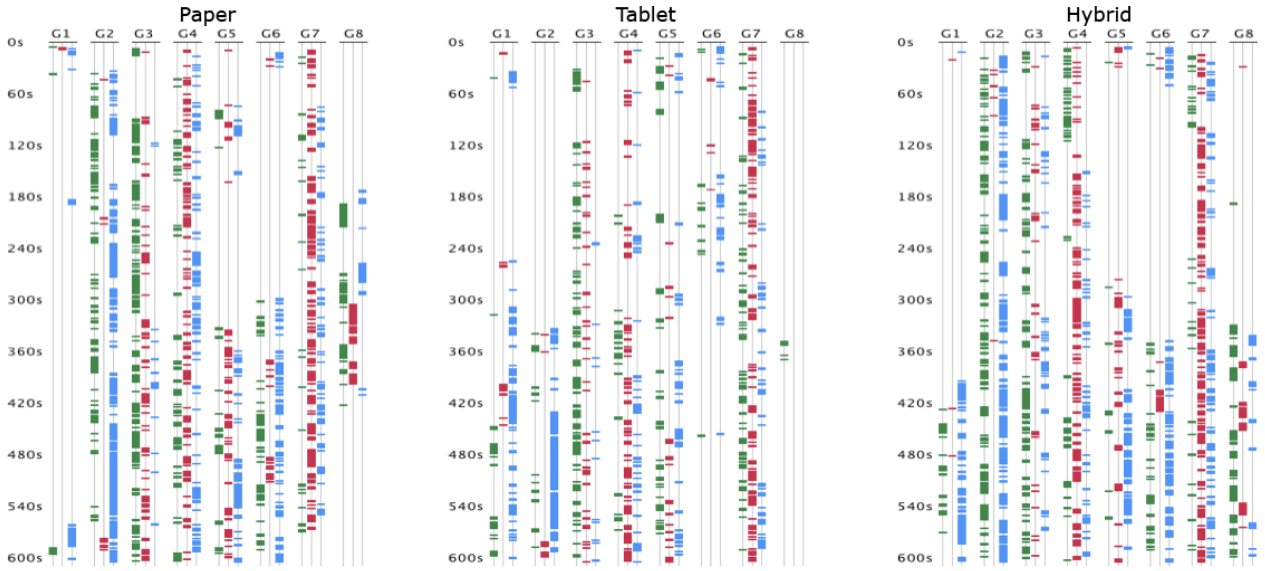

Figure 6: Verbalization Patterns: Y-axis presents time, X-axis groups and conditions (3 people per group).

not provide statistical analyses of these, we present evidence backed up by specific examples and the number of occurrences in different conditions. The most relevant observed events relate to sharing behavior of either paper or tablets, simultaneous use of multiple document and devices (including their spatial arrangements), and simultaneous usage of multiple technologies in the hybrid conditions.

5.2.1 *Sharing and Pointing on Paper and Tablets*

All groups, except one, shared paper documents at least once. By sharing we refer to instances where more than one person is looking at one document, sometimes with one of them also pointing or orienting the object to another person. For example, Fig. 7 shows instances of two people looking simultaneously at a paper document (left) and a tablet respectively (right). However, these episodes happened less often in the tablets condition, and only 5 of the 8 groups simultaneously used information on the same tablet. Interestingly, people passed each other paper documents very often (mostly at the beginning of the task), whereas this did not happen in the tablet conditions: participants just picked up a device for themselves.

5.2.2 *Multiple Documents*

Fig. 8 shows two of the many instances of multiple documents being used simultaneously by a participant. This was common in all conditions, but less common for tablets: only three tasks of 24 had no instances of multiple document use and these were all tablet tasks. One particular kind of multiple-document use, spatial arrangement of multiple documents on a surface (e.g., see Fig. 9), was very common with paper—we observed this in all tasks where paper was present. With tablets it did happen (Fig. 10), but it was less common: it happened in 5 of 16 tasks that involved tablets.

Our observations indicate that these spatial arrangements usually corresponded to the order in which the group intended to use a particular idea within the final outline. Thus, spatial arrangement becomes a way of sketching the structure of the document before it is done. Participants seemed to more easily recognize their ability to do this with paper documents than with tablets, but this might still be

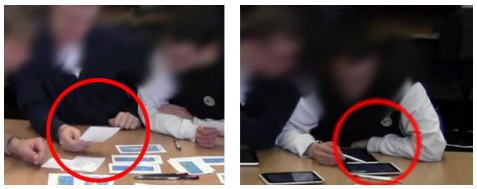

Figure 7: Left: group examining a single piece of paper. Right: partipant pointing to digital document with a stylus as group member looks on.

Figure 8: Participant holding and making use of two paper documents simultaneously.

due to the physical constraints of the tablets, at least partially. For example, paper is lighter and easier to shuffle to different positions (without awkwardly bumping tablets onto each other). In fact, there was an instance in which the disposability of paper shows how much more flexible paper still is than digital media: one group decided that the granularity of document groupings was not sufficient for their outline and they split a paper document into multiple pages to be able to spatially construct their outline with multiple pieces of a single document (see Fig. 11). A similar interaction is possible with tablets (i.e., selecting different parts of the document in multiple tablets) but was not used.

We also observed a behavior on paper that is somewhat inverse to the previous example: participants often turned over paper booklets to take notes on the white back page, effectively combining two documents (an original document, and a user-generated one) into one. This could have two possible advantages: it keeps some information together that belongs together, and it might save the reader some physical

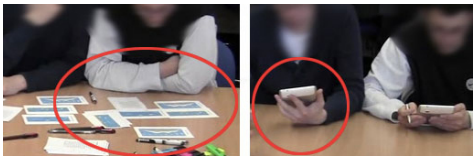

Figure 9: Left: spatial arrangement of multiple paper documents. Right: typical individual tablet use.

Figure 10: Spatial arrangement of multiple tablets.

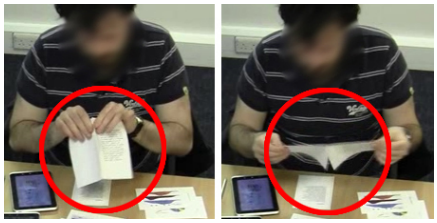

Figure 11: Tearing apart a page into multiple pieces.

Figure 12: Switching from paper to digital.

	Q1			Q2			Q3			Q4		
	best	middle	worst	best	middle	worst	best	middle	worst	best	middle	worst
paper	15	6	3	18	3	3	20	3	1	14	8	2
hybrid	1	15	1	2	12	9	3	14	7	10	10	4
tablet	8	3	20	4	9	12	1	7	16	0	6	18

Figure 13: Participants' feedback on their condition preferences. Numbers indicate counts of participants who rated that condition best/middle/worst.

work to have to reach (or walk) to get a new blank piece of paper from the center of the table.

5.2.3 *Multiple Technologies*

In the hybrid scenario we observed relatively frequent switches of technology such as the one shown in Fig 12. Each participant switched from paper to tablets or vice versa an average of 7.8 times in the 10 minutes of the hybrid condition, even though participants knew that they could use their technology of choice and that they already had experienced both separately.

5.3 Subjective Ratings and Comments

Participants ranked the conditions based on four key areas (Q1: ability to perform task, Q2: comfort, Q3: ease of use, Q4: supporting group work). The results show a strong majority preferred paper in all four aspects (Fig. 13).

Although some participants said about the tablets that they were "natural", a good "option to take notes", and less cluttering than paper which would "quickly get cluttered", participants "felt more comfortable" with paper and found that, with paper, it was "easier to see what other people were working on". Paper also allowed study participants to, "[easily] switch between documents & compare info", and was, "easy to share".

Participants also made negative comments about the digital tablets that might point to the strong differences in preference and perceived value. For example, participants noted that digital tools made, "going back and forward [between documents] . . . confus[ing]" and that "have[ing] to switch from graphic / document to [digital] scrap paper, [meant that they] can not look and copy concurrently", and that the tablet task was missing a "separate [physical] sheet of paper (tablet) to write notes as you are reading". Note that participants stated these objections even though such concurrent usage and separate note taking was possible by way of using multiple digital tablets simultaneously.

6. DISCUSSION

In this study we investigated the use of tablets replacing paper for co-located collaborative intellectual work. More than a decade after Sellen and Harper's reflections on the advantages of paper, and in spite of the many technological advances in tablets, we found that paper is still overwhelmingly preferred to tablets and to having both tablets and paper (at least for intellectual collaborative tasks such as ours). Our objective measures also show definite differences between the two media in communication and collaboration patterns; with tablets, people spent more time looking at their tablets and less at other participants (50% less). Additionally, our observations suggest that providing the information through tablets results in fewer instances of synchronous sharing of the documents, and that paper also lends itself better to the use of multiple documents simultaneously by the same person.

Our study and analysis can help us understand the tradeoffs between paper and its replacement technologies in order to inform the future of electronic media [31]. Previously, we could perhaps speculate that paper's advantage is due to a lack of familiarity with the technology, or to the lack of maturity of the interface; however, we tested a technically-savvy participant pool, in a context and at a time when tablets are very common. We also did not observe people having problems with the extraordinarily simple interface. Although we do not have a comparable measure of preference from a decade ago, we think that the lower preference for tablets is the result of other factors.

One of the factors that Sellen and Harper identified as possible shortcomings of the (then current) digital document delivery methods was the ability to look at more than one document at the same time and to be able to cross-reference information without much navigation. We addressed this in our study by providing multiple devices per person that could be easily moved and placed side by side or in other arrangements, as we see happened with paper in our own study. However, we observed only limited instances of multiple simultaneous tablet use. Moreover, sharing electronic devices with others was also rare. Therefore the preferred

multiplicity between collaborators and devices seems to be one-to-one, unlike with paper where it is many-to-many.

We hypothesize that *people still consider digital devices as personal devices, and this results in a somewhat compromised collaboration* (less sharing, less flexible use of tools). However, our quantitative evidence on the difference in gaze behavior and the reduced speaking time of groups with tablets (almost 50% more speech with paper than with tablets) suggests an alternative, perhaps more interesting hypothesis: *digital devices capture more visual and cognitive resources, which force participants to pay less attention to each other and results in noticeably compromised collaboration.* This is consistent with previous research on the distribution of visual feedback in co-located collaborative environments [26]. A final hypothesis is that tablets are not necessarily harder to use by a single person, but that *digital devices make it harder to gain awareness of what others are doing.* This could be a consequence of the dynamic characteristics of tablets: unlike paper, the content of a tablet is highly mutable, and it can be hard for people to keep track of which documents are currently being read by others.

6.1 Limitations, Generality, and Future Work

Through our study, we have been able to explore verbal and gaze factors that affect collaboration with digital and paper devices. Naturally, our methodology, as with all empirical methodologies, has limitations that can only be addressed through further experimentation and method triangulation. For example, it is possible that the trend towards tablet-as-personal-device is just a historical artefact of a technology in transition. Additionally, other effects might become significant when the tested behavior that spans over hours, days or years instead of short tasks.

In our efforts to provide balanced capabilities across paper and tablets, we specifically did not provide the ability to electronically share documents when using the tablets. Although sharing documents would have been of limited use in a closed task like ours (all tablets contained all documents), introducing digital capabilities that are impossible with paper may well push the results towards a digital preference (e.g., sharing annotations). Several participants stated that the digital tablets should allow them to, use a "... shared [digital] workspace [in order] to collaborate", which indicates that they are aware of the possible advantages of using digital media over paper in terms of features. Introducing advanced digital features in the study was risky, since it could interfere with the usability of the software, and almost any such feature would be unfamiliar to participants.

Therefore, our study was not designed to ascertain if the overall value of the different media differ (this is a wider question requiring other methodologies), but rather to find out if the use of the different media for these simple tasks would cause changes in behavior and communication patterns. The sub-tasks that our participants did in our scenario (reading, annotating, compiling information, discussing, etc ...) are fundamental enough to assure that they could be carried out during co-located collaborative tasks using the basic tablet software we provided participants. Nevertheless, in generalizing the results of this research study it is important to be aware of the key advantages of digital media which did not come into play (e.g., document sharing).

Additionally, all our measures focus on the process rather than on the outcome. Judging the quality of the outlines is difficult and, for a necessarily small study like ours, vulnerable to large amounts of statistical noise from individual differences and from the evaluations by external judges. Future (and larger) studies can focus as well on the quality of the output, as well as in other aspects that we had to leave out of our scope, such as participant's reactions to the annotation capability and their ability to compose documents completely within the digital interface.

Finally, the three hypotheses proposed in the previous section are, necessarily, still conjectures derived from our results. However, they can be valuable reference points for further experiments that will help us address the limitations of current collaborative reading and writing technology. We plan to design longitudinal and laboratory experiments to shed more light on these hypotheses.

7. CONCLUSION

In this paper we present a study of group work on a co-located collaborative task that compared paper to tablets and a combination of the two. The results indicate that paper is still overwhelmingly preferred as the tool of choice in this task, even when multiple tablets are available for the same person. Several of the results can be useful to explain why participants preferred paper to the other conditions: tablets are mostly used by a single individual, multiple tablets are less often used simultaneously by the same person, and tablets seem to reduce the amount of time that people look at and talk to each other.

The state of tablet devices and our relationship to them is still very much in flux. Participants appear to treat electronic devices as personal devices as compared to paper documents which are seen as person independent, disposable, and modifiable. While we expected to observe similar cohesive group collaboration with the hybrid conditions this was not the case. However we reconfirm a generalized preference for paper documents and show how tool selection may impact collaborative intellectual work. The general acceptance of and preference for paper documents stated by our participants indicates electronic devices and paper documents should not be simply interchanged without acknowledging that tool selection may significantly affect group interaction. Interestingly, the preferred multiplicity between collaborators (tablets: one-to-one, paper: many-to-many) might have a big impact on collaboration scenarios. At this time, while accounting for the uptake of hand held electronic devices, we should still not assume the superiority of digital documents, specifically for collaborative tasks. Further and timely comparisons of digital and paper tools should be readdressed by the HCI community as the adoption and acceptance of digital tools continues to grow and mature.

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