Understanding the materiality of writing from multiple sources

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Writing research has typically focussed on the text production elements of writing. Many everyday writing tasks, however, cannot be characterized simply in terms of text production since they often involve the use of source materials to support the composition process. As such, these tasks are better thought of as hybrid tasks. Such hybrid tasks have been given relatively little attention in the literature and what little work has been done has taken a purely cognitive approach that downplays the material context within which the task takes place. Following Haas' critique of mainstream writing research which advocated the need to consider the material tools and artefacts in theories of writing, this paper takes a similar approach in relation to the hybrid tasks of writing while reading from multiple sources. A study is presented that explores a range of everyday writing from multiple sources in their real-world contexts. The study highlights a number of important characteristics of the interaction with the material artefacts used during these tasks and the impact that these have on the underlying cognitive processes. The hope is that these will begin to offer some grounding on which future theoretical understanding of these hybrid tasks can build, as well as providing useful insights into the design of technologies to support these tasks.

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KEYWORDS: reading; writing; distributed cognition; materiality; ebooks.

1. General introduction

The support of writing activities has been an impetus for many important technological developments over the years including most notably, word processors, hypertext

authoring tools and collaborative writing environments. While these developments have had an important impact on writing behaviour, much of the focus for their design has been only on the text production elements of writing and the document being produced. For example, word processors are focussed primarily around the viewing and manipulation of the composition being produced as opposed to the viewing and manipulation of supporting source materials from which a writer might draw information and ideas. However, if we consider many everyday activities that we call writing, it is clear that they cannot be characterized just in terms of the text being produced. In a study of economists at the IMF, for instance, Sellen and Harper (1997) showed that while composing new policy documents, economists would spend almost 90% of the time reading and referring to other documents while writing. Likewise, in a more specific study of work-related reading and writing across a range of different professions, a significant proportion of people's document work was found to involve reading source materials during text composition (Adler Gujar, Harrison, O'Hara & Sellen, 1998). These kinds of activities, then, are better thought of as hybrid tasks in which there is a need to read, comprehend, synthesize and integrate information from multiple source documents during the generation of new compositions (Spivey & King, 1989).

By acknowledging the hybrid nature of many everyday writing activities, we begin to open up interesting new directions for developing technologies that further support everyday writing. In order to identify what these directions might be, it is first necessary to gain a greater understanding of these hybrid tasks. In particular, there is a need to more fully explicate the role of interacting with reference and source materials while writing in shaping the planning and generation of text. This paper presents our initial attempts to further our understanding in this domain through a study of real-world writing from multiple sources, across a range of different professions.

1.1. THE LITERATURE

To ground our discussion, it will be useful to consider some of the considerable research into writing that already exists in the psychological literature. While there are a number of key psychological theories about the writing process (Flower & Hayes, 1981; Bracewell, Frederiksen & Frederiksen, 1982; Bereiter & Scardamalia, 1987) perhaps the most influential of these has been that of Flower and Hayes (1981). For Flower and Hayes, writing is essentially a problem-solving task in which the writer has a rhetorical goal to achieve within the constraints of various assumptions and within the social context that the writer is embedded. The model suggests that the writer engages in various processes that are interleaved with each other throughout the course of writing, namely, PLANNING, TRANSLATING and REVIEWING. PLANNING is the process by which the writer GENERATES and ORGANIZES ideas and goals, drawing on prior knowledge, and schemata. TRANSLATING is the process of taking material from memory under the guidance of the writing plan and converting it into acceptable sentences. REVIEWING consists of READING to detect problems in writing conventions, inaccuracies of meaning, goal attainment and EDITING to implement the necessary changes.

Like the majority of the writing literature, however, the theory constrains itself to text production aspects of writing. Much less effort in the field has been given over to explicitly studying the hybrid kinds of reading-to-write tasks previously alluded to in an attempt to understand the mutually dependent relationships between reading of source texts, writing and constructing task representations (Spivey & King, 1989; Ackerman, 1990; Flower, 1990*a*,*b*; Stein, 1990*a*,*b*; McGinley, 1992). Again, it is the work of Flower (1990b) in this domain that more completely develops the theoretical foundations of the domain. Essentially, she extends the earlier Flower and Hayes (1981) model of writing by incorporating the additional processes of NOTICING cues from source materials and the EVOKING of relevant memories. These processes continually impact upon and shape the writer's task representation (goals, constraints and strategies) and are themselves continually impacted upon by the writer's task representation.

The theoretical work to date in the literature provides us with some useful concepts and vocabulary for thinking about writing in general and in particular writing from multiple sources. However, as with many cognitive theories of behaviour, this work seeks to explain the writer's behaviour purely in terms of internal mental processes with little explicit regard for the artefacts used for the task and the environmental context within which these behaviours take place. By not explicating the role of the technology and the artefacts used for the writing and reference to source materials, this theory and others like it falls prey to what Haas (1996) refers to as the "Technology is Transparent" myth—that cognitive tasks such as writing, and by extension, composing from multiple sources are assumed to exist independent of and be uninfluenced by the means of producing it (cf. Scribner, 1984; Larkin & Simon, 1987; Lave, 1988; Payne, 1991; Zhang & Norman, 1994; Hutchins, 1995; O'Hara & Payne, 1998, 1999; Hollan, Hutchins & Kirsh, 2000).

This type of critique of a purely internally driven cognitive theory has been taken up more broadly by various authors in an approach known as Distributed Cognition (Hutchins, 1995; Hollan *et al.*, 2000). What Distributed Cognition seeks to do is extend the notion of what is cognitive beyond the boundaries of an individual. It seeks to explain cognitive behaviours and performance in terms of the interaction between people and the resources and artefacts available to them in the external world. Cognitive processes are argued to be distributed across internal and external structures—across people, artefacts, space and time. In contrast to the ways in which traditional cognitive psychology has dealt with external structures in relation to cognition, Distributed Cognition argues that the relationship between internal and external structures is more than simply a re-representing of the external world in internally encoded models. Rather, it involves the ways in which we can dynamically configure these external resources and artefacts to coordinate with memory, attention and to facilitate perception, simplify choice and minimize internal computation (Kirsh, 1995; Hollan *et al.*, 2000). For example, O'Hara and Payne (1998, 2000) looked at how the variable ability to interact and manipulate external representations impacted on people's cognitive strategies during problem solving. When the effort and time costs of interacting with an external representation were low, manipulation of the external representation was used far more heavily as a problem solving resource than when effort and time costs were increased. With high effort and time costs associated with

manipulating the external representation, people had to resort to greater dependence on manipulation of internal representations which, while more cognitively demanding, actually facilitated learning. While the domain of the study was relatively artificial, it nevertheless illustrates how even subtle changes in the ways that people can interact with an external resource can have important consequences for their performance and the ways in which cognitive processing is distributed across internal and external structures.

The configuration of the external environment, then, is thus very much dependent upon the material properties of the environment and the interactional properties they afford particular actors. The artefacts and external resources with which we interact are a fundamental part of the cognitive systems itself and, as such, any understanding of a task domain must encompass these (Hollan *et al.*, 2000). To understand any situated cognitive task, such as writing from multiple source materials, it is important to go beyond the understanding of how the mind works as depicted in purely cognitive theories such as Flower's (1990*b*). Rather, it is additionally necessary to understand how the information to be processed is dynamically configured in the material world and how the material properties of artefacts cause cognitive processes to be distributed in beneficial or problematic ways. It is in this respect that Distributed Cognition can provide an "effective theoretical foundation for designing and evaluating Human–Computer Interaction and a fertile framework for designing digital artefacts" (Hollan *et al.*, 2000). More specifically, in this paper we want to argue by extension that it provides a useful theoretical framework for understanding the task of writing from multiple source materials in a way that can help think about the design of emerging digital technologies that aim to play a role in these tasks such as, for example, electronic books and digital libraries.

There have, of course, been many studies of the impact of artefacts and their material properties on writing-related behaviour both in individual and collaborative environments (e.g. Haas & Hayes, 1986; Gould *et al.*, 1987; Hawisher, 1987; Hansen & Haas, 1988; Haas, 1989*a*; Halio, 1990; Kraut, Galegher, Fish & Calfonte, 1992; Neuwirth, Chandhok, Charney, Wojahn & Kim, 1994; Shipman & Marshall, 1999, Marshall, 1998*a*, *b*). These studies have demonstrated various effects such as speed differences in composition between different computers and paper (e.g. Gould, 1987; Hansen & Haas, 1988; Haas, 1989*a*); differences in writing quality between different types of computers and between computers and paper (e.g. Hansen and Haas, 1988; Haas, 1989*a*; Halio, 1990—though Gould *et al.*, 1987, found no difference,) and differences in process such as the amount of planning activities that take place when writing [e.g. Haas (1989*a*) showed greater planning times with pen and paper compared with computers]. Studies have also shown how people do not easily accept new modes of authoring but rather that they try to incorporate existing practices within the bounds of new authoring tools such as hypertext authoring systems. These new hypertext authoring systems have different material properties from other authoring systems such as word processors and create a new formalization of structure within which authors must work. Authors tend to resist and when these formal structures are combined within existing authoring practices, it leads to unanticipated behaviour (Shipman & Marshall, 1999).

There is also a large body of knowledge concerned with the material properties of artefacts that impact on reading behaviour focussing in particular on the differences

between reading on paper versus reading on screen [see Dillon (1992) for a comprehensive review]. The majority of the work has focussed heavily on outcome measures such as speed (Muter, Latremouille, Treunit & Beam, 1982; Wright & Lickorish, 1983) proof-reading accuracy (Wright & Lickorish, 1983; Gould & Grischkowsky, 1984; Creed, Dennis & Newstead, 1987) and comprehension (Muter *et al.*, 1982; Egan, Remde, Gomez, Landauer, Eberhardt & Lochbaum, 1989). With regard to measures such as speed, the literature generally points to performance deficits when reading from a screen, though as Dillon remarks, methodological differences across the studies result in interpretational difficulties. Since these studies, though, there have been advances in screen technology with which the reading speed advantages of paper over screen disappear (e.g. Muter & Maurutto, 1991). With proof-reading accuracy, performance deficits for on-line reading have been demonstrated but only when the task goes beyond the demands of mere spelling checking. These measures illustrate interesting differences between paper-based reading and on-line reading. However, it is questionable how informative such gross outcome measures are in explaining reader preferences, especially since it is unclear whether the reader even perceives such differences. Outcome measures such as comprehension may be more informative in explaining differences since comprehension monitoring is an essential component of skilled reading (e.g. Oakhill & Garnham, 1988). The literature has generally suggested no negative effects of electronic text on comprehension. However, it is argued by Dillon (1992), that this may be due to the insensitivity of the comprehension measures used (e.g. question answering ability) to potentially subtle cognitive differences caused by presentation medium. This is consistent with the claims of Hansen and Haas (1988) concerning the difficulties of developing a sense of text structure and semantic arrangement when reading on-line.

A lesser effort has been devoted to comparing the process differences between reading on paper and reading on screen. That is, how the reader interacts with the text, how they look at text in terms of eye movements, how they manipulate it, and how they navigate through it. Eye movement studies tend to reveal no major differences between paper and screen-based technologies (e.g. Gould *et al.*, 1987). As for manipulability, paper is generally regarded as the more manipulable medium (e.g. Richardson, Dillon, McKnight & Saadat-Samardi, 1988). With regard to navigation, there is general agreement that readers of electronic text have much more trouble knowing where they are in a text and finding their way to desired locations within the text (e.g. Dillon, Richardson & McKnight, 1990; O'Hara & Sellen, 1997).

With these findings in mind, Hansen and Haas (1988) and more recently Haas (1996), have developed a theoretical framework that articulates some key media characteristics for explaining these differences between different computers and between computers and paper. The primary characteristics that they discuss are page size, legibility, responsiveness of the system and tangibility of the medium. The secondary factors within their framework are sense of directness, sense of engagement with the system and perhaps most importantly sense of text (i.e. understanding of the structural and semantic arrangement of the text). This framework provides us with some further useful conceptual tools with which to think about research studies of writing, reading and writing-related reading in relation to the technologies and artefacts used.

As well as discrete writing activities and discrete reading activities, a number of authors have also looked at writing-related reading and reading-related writing with reference to the effects of different artefacts and their interactional properties. For example, Haas (1989*a*) demonstrated more extensive re-reading of their compositions and text revision with computers compared with paper. Others (e.g. Chalfonte, Fish & Kraut, 1992; Neuwirth *et al.*, 1994) have shown how document review and revision strategies in collaborative writing tasks are influenced by different modalities. Such differences include the type of text problem reported and the tone in which they were reported. Reading-related writing, namely annotation and note-making has also been examined with reference to paper versus electronic texts and hypertexts (O'Hara & Sellen, 1997; Marshall, 1998*a, b*). Marshall's work is perhaps the most comprehensive in terms of unpacking a range of purposes and dimensions for annotations (e.g. formal vs. informal, explicit vs. tacit, permanent vs. transient, published vs. private, etc.) during reading. These provide a useful framework within which to think about characteristics of information artefacts such as paper and hypertexts in relation to annotation support.

This extensive set of research into the material characteristics of reading and writing help inform some of our concerns in this paper. However, they do not fully address our concerns here with the hybrid task of writing from multiple source documents. These kinds of hybrid tasks have received considerably less attention in terms of exploring the impact of particular artefacts on the cognitive processes and behaviours. The most significant work in this area has been by Neuwirth and Kaufer (1989), who provide an excellent explication of the role of external representations during a synthesis writing task. As developing a cognitive theory of the synthesis task, the work is particularly useful in outlining a framework for studying the role of representations that can help compare and contrast how different information artefacts would impact on the synthesis process. For example, the framework provides a list of criteria for determining why a particular external representation is better than another and as such is important in informing the concerns of this paper. The framework was used to help design a hypertext-based external representation to support the linking together and structuring of ideas necessary during a synthesis task. In spite of their useful theoretical characterization of the task and the role of external representations, the explicit material analysis of the work focussed primarily on these specialized tools that they developed. The emphasis of their work was much less on the material characteristics of the source materials themselves and their relationship with authoring tools and how these shaped the cognitive processes underlying the hybrid task of writing from multiple sources.

With this in mind, then, the current paper presents a study of real-world writing situations in which a range of different writers used source materials to compose new texts. The primary focus of the study is on the interaction with the source materials themselves and their relationship with the writing task. The aim of the paper is to begin to explicate some key aspects of the interaction with the physical artefacts that occurs during these hybrid-writing tasks and the ways in which such interactions shape the cognitive processes. As with much of the previous work that has discussed the role of technology and artefacts in relation to writing, a core theme of the current study is the relationship between paper and on-line documents and their respective material

characteristics. By highlighting the material aspects of these types of reading-to-write tasks, the aim is to complement existing theories and to offer a fresh perspective that can aid their development. Further, this approach can offer important insights from an applied perspective. By working within the framework of Distributed Cognition, we aim to understand the cognitive consequences of these material characteristics and how cognitive structures are distributed across internal and external representations. This will provide a useful basis within which to assess the role of technology in support of such hybrid tasks particularly in relation to the use of source materials. The paper will illustrate this by an example through a discussion of certain technologies such as the emerging generation of ebooks and PC-based reading software, explicating ways in which current designs might need to change in order to successfully play a role in such tasks.

2. Method

2.1. PARTICIPANTS

Participants were drawn from a range of professional and academic jobs to allow a broad range of writers and writing to be examined *in situ*. The resulting sample comprised 10 participants: two consultants, a contract lawyer, a professional support lawyer, a researcher from a local examination syndicate, a writer from an overseas aid organization, an information technology journalist† and three doctoral students. The students were paid £25.00 for their participation. All others participated voluntarily.

2.2. WRITING TASK

Each of the participants was carrying out a real-world writing task as part of their job or studies. These different writing tasks then formed the basis of the study. The writing tasks studied were at various stages of maturity, ranging from those in early planning stages, through composition, to editing and review stages.‡ In order to get some general sense of the writing that participants were undertaking, Table 1 presents a brief description of their specific writing tasks.

2.3. PROCEDURE

Each participant was asked to suggest a time when they were going to be engaged in some form of writing activity involving referring to multiple source materials. At this

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†The journalist unfortunately had "Writers' Block" when the experimenters visited and so it was not possible to carry out the full procedure used for the other participants. However, it was possible to conduct an interview with him about his writing and use of supporting source material in general. While this did not provide the same richness of material that was possible to gain from the specific writing episodes of participants under the full procedure, it nevertheless provided some useful insights that justified inclusion in the study.

‡It is recognized, as Flower points out, that these different aspects of the writing task are in fact interleaved throughout the entire writing process. However, the aim here is to give the reader some high-level indication as to the state of progress of participants in their different writing when being observed.

TABLE 1
A brief description of the writing tasks undertaken by each participant

Participant	Writing task	Source materials used	Primary activities
Consultant (MM)	Planning a slide pre-sentation centred on a debate in a particu-lar journal article.	A variety of books are used for reference to provide general context for the pre-sentation before focussing on the spe-cifics of the debate. He also has a note-book of his own thoughts and ideas.	Primarily engaged in paper-based brain-storming, note-mak-ing and planning in relation to these ma-terials before trans-ferring the information to on-line presentation package.
Consultant (HG)	Planning a report about the pros and cons of terminology and jargon use.	Working from meet-ing notes plus inter-net printouts and various books.	Primarily engaged in searching through books and printouts in reference to infor-mation meeting notes to create paper-based notes and a plan for the composition that was subsequently transferred to the PC for embellishment.
Contract lawyer (CO)	Planning and com-posing a reply to a client regarding con-tract amendments.	history of email com-munication between three parties, both on-line and on paper versions plus printout of the contract in question.	The lawyer has to make reference to the contract in order to suggest amendments that simultaneously address the concerns of the client and the third party specified in email thread.
Professional support lawyer (SW)	Planning and com-posing fortnightly departmental news-letter.	Meeting notes from departmental meet-ings; batch of letters from fee earners; a large selection of property and law journals; new prop-erty cases; various bulletins and maga-zines; Internet print-outs.	Sifting through and organizing a large se-lection of material into piles for the reg-ular newsletter sec-tions. Summarize the key points from the collection of materi-als.
Researcher from a local examination syndicate (SH)	Planning and com-posing paper for a conference about a tool for assessing dif-ficulty of examina-tion questions.	Selection of section printouts from a large report that the group had written about the use of their tool for different educational subjects; journal arti-	The major part of the planning involves a comparison between an existing tool and the tool they have adapted from the existing tool. This

TABLE 1
Continued

Participant	Writing task	Source materials used	Primary activities
		cles about the original tool, a draft of a plan, both on-line and printed out; printouts of interviews with the children and examiners; and syllabus materials.	involves initially making paper-based notes that are then developed into a plan on the PC.
Writer from an overseas aid organization (AR)	Writing of a section in an educational publication about the impact of tourism in Kenya.	Several books on the geography of Kenya and about the general impact of tourism on a country and its people, government reports containing tourist and economy statistics, plus paper and on-line notes from interviews of Kenyan people about their life and the impact of tourism.	Integrating information across source materials and using source materials to build a structure of quotes and paraphrases on which to elaborate an argument.
Student: English and American literature (SHVY)	Writing a subsection of a chapter in her Ph.D. Thesis about the connection of ideas between an English poet, Coleridge, and an American essayist, Emerson.	Using various primary material from Coleridge and Emerson, plus various books and annotated photocopied articles of criticism. Also has to hand a huge database of relevant quotes both on-line and printed out.	Integrating information across source materials and using source materials to build a structure of quotes and paraphrases on which to elaborate an argument. Uses paper database for more nonspecific search for relevant quotes and then copies these from electronic database into composition to create structured and flowing argument.
Student: Art and literature (WW)	Re-writing the introductory chapter to Ph.D. Thesis on relationship between the poetry of Dante and the paintings of the Rosettis.	Working from: primary materials—'"books of poetry and art; books and journal papers of criticism—in particular, the work of a certain critic with whom she	Integrating information across source materials and using source materials to build a structure of quotes and paraphrases on which to elaborate an

TABLE 1
Continued

Participant	Writing task	Source materials used	Primary activities
		disagrees; personal notebook of thoughts and ideas; printouts of previous drafts of the chapter.	argument. Referring also to ideas and arguments in personal notes and previous versions of chapter to glue these together—reading and restructuring the information in these notes to create the new composition.
Student: History and Philosophy of Architecture (GS)	Writing a subchapter for Ph.D. Thesis on history and philosophy of architecture.	On-line and printed versions of notes based on readings of source materials plus her thoughts in relation to materials. Some of the prose within these notes is in more or less complete form for inclusion in the thesis while other bits are quotations or incomplete expressions of thoughts and ideas.	The writing task is primarily one of restructuring which involves reference to the paper-based version of the notes to make and then creating a new on-line composition by copying and pasting from existing notes files to new composition file and then reworking for coherence and completion.

time, two experimenters visited the participant at his/her place of work. An initial 15-min interview was conducted to explain the purpose of the study and the procedure. In addition, the interview was intended to elicit background information about the writing task that the participant was working on and more specifically, what particular aspects of the task he or she was going to be focussing on at that specific point in time. With this interview complete, each participant was then asked to proceed normally with his or her writing activities. These activities were video-recorded, with the camcorder set-up to capture as much of the desk area as was necessary to view both the actual text production behaviour as well as any reference to source materials. Participants were not asked to provide any verbal protocols while writing as it was felt that this might hinder the natural flow of their writing and reference behaviours. During the session, both experimenters observed each writer and noted down any interesting issues that they could later raise during the debrief interview. After approximately 40 min, the experimenters asked the participant to stop writing when they reached a convenient point for a break.

   Participants were then given a short break while the experimenters prepared for the debrief interview. The debrief interview took approximately 1 h. The initial part of the interview was semi-structured consisting of several open-ended questions about

the writing session and their cross-referencing activities. For the rest of the interview, participants were then shown video clips of themselves during their writing that the experimenters had noted as being interesting or in need of explanation. The video clips provided the participants with useful cues to re-establish the context of the writing and referencing activities at particular points of interest. Participants were then able to explain what they were doing during the clip and the reasons why they were doing it in particular ways. They often used their written output and reference materials in support of this discussion. After the interview was completed, the experimenters took copies (or requested them to be sent later) of the written output and as much of the source materials as was practically possible.

2.4. ANALYSIS

In order to develop as complete a picture as possible for each session with the participants, it was necessary to combine the data from various sources. The observational data from the video were considered in the context of participants' descriptions of what they were doing both in general and at particular points of interest during the observational period. Using this information and by studying the final compositions and the source materials, it was also possible to establish what part of the composition was being written at the time and also what pieces of the source text were being attended to. This combined data made it possible to infer the relationships between information in the source materials and information in the written composition and thereby some of the cognitive processes involved at particular points in time. These could then be considered in the context of the observed interactions with the material artefacts occurring at those times.

3. Findings

The findings are organized into four major sections. The first section examines how and why each participant's focus of attention was transferred across the composition being produced and the source materials being used. The second section discusses issues of spatial layout—how documents were organized specifically for the task and the ways in which this supported visualization and processing of the information across the sources and written composition. In the third section, we consider the role of annotation and mark-up of the source materials in the writing activities of the participants and the ways in which it was used to support thinking and planning activities, navigation and restructuring of information. A final section then discusses the simultaneous use of paper and electronic versions of the same document and the ways in which the respective characteristics of each were deliberately exploited by the participants for particular parts of their writing behaviour.

3.1. MOVEMENT OF ATTENTION ACROSS SOURCES AND COMPOSITION

One of the most important features of working with multiple source materials that we observed was the movement of attention and visual focus back and forth between

different source documents or between the source documents and the written document. Indications of this included eye gaze and head turning, confirmed by participants' comments during interviews. This movement occurred, for example, when comparing and contrasting information across different sources, when copying information from a source document to the written document, when paraphrasing information from a source document, when referencing facts, when integrating ideas across the source documents, or to see how information from the source might flow on from the information in the composition.

These activities appeared to involve a complex interplay between the knowledge in the writers' heads and the physical and informational characteristics of the external source documents and compositions. This can be seen in the following extracts from the transcriptions:

Extract 1:

SHVY: "Yeah. I think that's where I finished this and I was looking for an "act of knowledge", which is this and I think I was starting to look for something else because I had written this first line up to "or in his words" and I was like "OK there's another quote I need from the Biographia" but this is such a small one that I couldn't find it in there so I think this is where I switch to the other book now where I get up and get up the other book."

K: Again how does it…Does it naturally follow on. I mean can you explain the follow on?

SHVY: "I mean the line [in her composition] is "Coleridge believed firmly in the intersection between Idealism and Materialism, he did state firmly that this intersection was achieved in a moment of seeing, or in his words, blah" so that's where I was like, well "moment of seeing" is sort of my paraphrase of it but in the Biographia he talks about an "Act of Knowledge" which I knew that that is what he called it. So I needed to look for this actual phrase…So that's why at that point I wanted to get…to make sure that I got the right wording for it, you know, his own wording because Emerson puts it in different terms than he does. And that is why I was looking through there [Biographia]…There's several passages which kind of get to this point and I was sort of thinking…I think I was thinking at that moment "Oh well that's kind of the right thing but there is a better quote out there". Also it's partly the way that Coleridge writes. You don't necessarily know where you are going to find the right thing because he sort of repeats himself a lot so you can get one version but then you think, "well I think there is a slightly better formulation of this" and I was looking for that one."

Extract 2:

WW: "Yes, I was copying a…I was copying this point and I was…er, this wasn't exactly what I wrote on that plan but I was thinking about it and expanding it and I had to glance back at it to remind my self of the direction it was going to go in."

While aspects of these cognitive processes cannot be fully explicated from these data, we could nevertheless gain important insights into some of the important features of the documents' materiality that impacted these processes. To illustrate, let us consider an example from the writing episode of the educational researcher (SH).

SH was preparing a research paper about "Scales of Cognitive Demand" for the purpose of assessing examination questions in science, geography and history. As part of this task, SH needed to compare the information about an original form of the scale with information about some new scales. Each scale of demand was represented in tabular format with a list of items in each cell. Each scale was also printed out
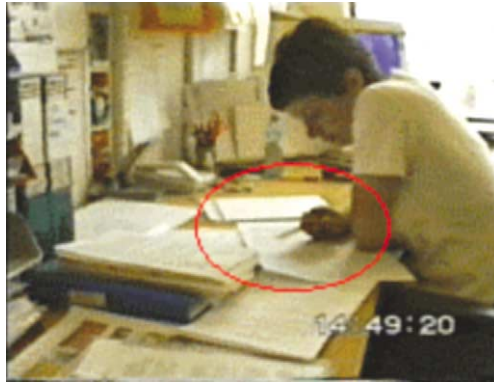
FIGURE 1. The layout of source documents and paper-based plan for the purposes of comparing and contrasting information.

separately. The printouts were laid adjacent to one another, which in turn were adjacent to the paper-based plan she was constructing on the basis of this information analysis. This was the first important feature of the interaction with the documents in that the spatial layout of the documents was specifically "designed" by SH in anticipation of the cognitive demands of the task. All three documents were arranged in such a way that they were physically as close as possible while they were all still permanently visible so that she could easily look across them (see Figure 1).

She then began the compare and contrasting activities for each of the two tables. To do this she had to take the information from one cell, maintain it in working memory and then look at the corresponding cell on the other document to see how it was similar or different. This was quite a work-intensive process. For example, when comparing the two scales on the single dimension of complexity, she glanced back and forth 13 times between the two printouts (with glances of the order of 0.5 s in the main but ranging up to 11.3 s) before committing to writing anything on the plan. This amount of attention transfer between the two documents for this single piece of the analysis provides some indication of the kind of cognitive complexity involved in the comparison process.

Because of the cognitive complexity of the comparison process, it helps to minimize the demands on attention (e.g. in terms of visually relocating the specific pieces of information in each document). This again points to some important material features of the documents and information layout. Paper documents have important properties that support a reader's awareness of the spatial location of information within text. Because the text on paper does not move in relation to visual reference points such as page boundaries, readers can reorient to the correct part of the page using the spatial cues of the page (cf. Rothkopf, 1971; Lovelace & Southall, 1983; O'Hara, Bentley & Sellen, 1999).

> SH: "Well because physically I know that when I open this, on the next page about half way down is going to be the information I need. But if I'm scrolling around I never know quite where I am starting from because I know I am starting from here (points to paper) and I know that it's there. And they all look the same. When you've got them on screen they all look the same, it's just words."

Similarly, with the paper composition document, participants could maintain the spatial position of their writing hand while glancing at the source materials. This meant that attention could be easily redirected to the correct place when looking back to the composition page. This allowed the *translation* process to more effectively combine information from the sources and the composition such that the writing flows.

As participants used source texts more, they developed a familiarity of the structure that supported their noticing and evoking processes, as illustrated in these three separate extracts:

> SHVY : "That's actually why I had to go over there (on bookshelf) to get the other book because I have the new edition of this Coleridge book but it's not marked up. And also there are places where I remember what things look like and of course it looks different in a different edition. So I had to get my old book to find it."

> GS: "Yeah I don't really read them, I recognise...and I recognise each paragraph."

> WW: "That comes after you have already read quite closely those materials. I mean this is the reason why there is this pile of books rather that the entire library 'cause these are the ones I have read and I have identified things in them so then when I am glancing at them I am just picking up those things that I saw before...It is a confirmation of what I have read before."

This familiarity allowed brief glances to trigger off knowledge in their head that somehow remained temporarily inaccessible until the trigger word, sentence or structural feature was attended to for the briefest of moments. In this example, there were additional visual and cognitive demands created by the nature of the information layout. The information to which SH was referring in the document was arranged in a tabular format with visually similar lists of items in each table cell. The visual homogeneity of the information format made the necessary preciseness of quick information access difficult without some additional behaviour. To compensate for this, SH would point simultaneously across both documents, creating more precise visual reference points for quickly relocating information within the documents (see Figure 2). This physical indexical behaviour was possible only because of the ability to lay the documents out such that they were both concurrently visible.

Many of these characteristics also applied when the composition document was on computer but there are some additional points of interest in these instances. Moving attention between the computer display and paper-based source materials could be more demanding due to the increased distance between the two spaces when compared with the paper-based situation as exemplified by SH above. This was indicated by the fact that for the more cognitively difficult information processing across screen and source materials, there were occasionally times when it became necessary to move the paper documents closer to the computer display. This reduction in distance would reduce the time taken to shift attention from source to composition, making it easier to maintain the information in working memory and combine it. What was particularly interesting was that in the situation where a word processor was being used to create the composition, these quick back and forth attention-shifting activities were never something that took place purely on screen, for example, by moving between windows. The participants in the study only ever had one window clearly visible at a time in this study such that it was possible to easily ascertain which document they were attending

FIGURE 2. SH using two fingers on one hand to point across two concurrently visible source documents.

to on screen. The movement of attention between documents on screen would only be for longer searches or for copying and pasting activities. Observations showed that the quick back and forth attention shifts occurred across the separate spaces of the paper source materials and the electronic composition on screen.

3.2. SPATIAL LAYOUT

3.2.1. Pre-organization of source documents. In order to support cross referencing of multiple documents while writing, the participants engaged in various pre-organization activities in which their paper source documents were physically arranged together in space. Comments from the transcripts suggested that the physical structure of their particular spatial layout of source documents was used to reflect the representation of the task that they had in mind.

"The way I structure my document is also the way I organise my working space." GS

An example can be seen from one of the participants, GS, the philosophy of architecture student who was editing a thesis chapter. She arranged a printout of the chapter into four piles that were tiled on top of each other corresponding to the four subsections of the chapter. Likewise, SH imposed a hierarchical arrangement on her reference documents (note these were printouts from electronic files that she had access to on-line) according to the structure of her planned composition. Six documents were arranged into three high level piles that were tiled on top of each other (corresponding to the three courses—history geography and chemistry). Nested within these three piles were more closely tiled pairs of documents (corresponding to different levels of examinations for these participants) (see Figure 3).

"Well these (the pairs of documents for each subject—A level and GCSE) all belong...these go vertically because they are all the same thing—because I'll only ever be referring to one of these at a time because they are all the same. And then right at the end because I didn't want to refer to it very often—probably wouldn't. And then I had piles of things in plastic envelopes and they were general bumph on the scale and general bumph
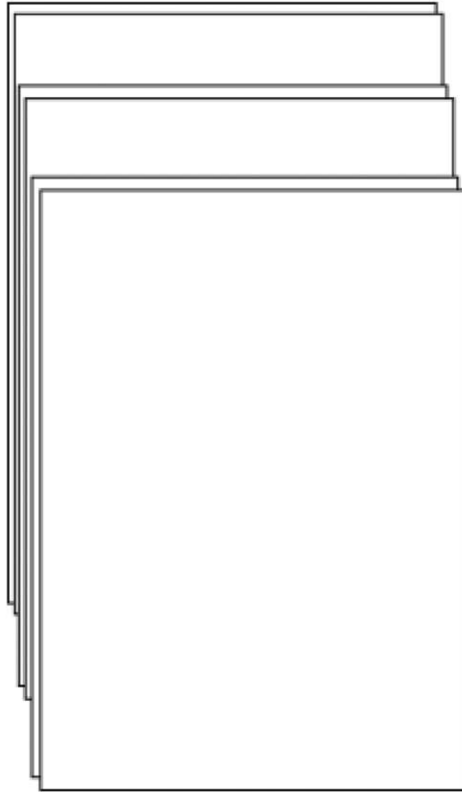
FIGURE 3. An example of the hierarchical arrangement of the documents.

on the repertory grid interview...Basically I was doing it by subject—History, Geography and then Chemistry. So history I looked at the change from phase one to phase two: original to not quite original scale." SH

These organized arrangements of the source documents helped the participant find information while writing. Using this kind of layout, she could use this positional information or "holding pattern" to help locate appropriate documents more efficiently when required rather than searching through the materials in a random fashion.

Physical groupings of the reference documents were also used to help develop a structure for the written composition by helping to organize large amounts of material. SL was a legal associate who would create a newsletter for the legal department to provide a high-level summary of Whites,† precedents and cases, etc. She would receive a large number of these documents (approx. 30–40) over the course of a month. When it came to writing it, she would begin by going through all the documents one by one and place them in different piles around her desk corresponding to different groupings of

†All fees earners produce letters and "whites" are carbon copies of each of these letters.

issues that she wanted to write about. Once this pre-organization of the documents was complete, she would then lift up the first pile and flick through documents in the pile to get an overview of the documents and information in that pile. This overview would then allow her to select the most relevant and important snippets from the documents that she wanted to include in the newsletter. She would then write by paraphrasing or quoting information from individual documents within the document groups that best provided a flavour of their main points. By having paper-based piles, she was able not only to organize the information but also easily maintain the structure of the information while flicking through the documents (see Figure 4). What was also interesting about this example was that some of the information used in the newsletters was from the Internet. This information was printed out so that the entire reference material was in a single format, namely paper. By having a single format, it was then possible to carry out the necessary pre-structuring of the information.

3.2.2. Spatial layout and visualization. The spatial arrangement of paper documents over the desks of participants had a number of implications for how the writers in this study interacted with their source materials. Spreading out these paper documents in a separate space from that of the computer display made the source materials visually available to the participant at any time during their writing process without sacrificing the visibility of the composition. The participants could easily notice distinctive visual characteristics such as the colour of a book, its size and its shape as they were writing or as they were searching the information space of the source materials. Such characteristics were often enough to *evoke* complex patterns of knowledge in the head or previous trains of thought in relation to a particular source text.

> INT: "do you actually get from just glancing—you just look at something very quickly and then continue to write. What are you getting out of what you are reading?"

> Right, um. That comes after you have already read quite closely those materials. I mean this is the reason why there is this pile of books rather than the entire library 'cause these are the ones I have read and I have identified things in them so then when I am glancing at them I am just picking up those things that I saw before.

FIGURE 4. An example from SW, the professional support lawyer using document piles to pre-structure the source materials from which to compose her summary document.

Being able to see many documents at once with minimal effort allowed relationships to be created that would be difficult if they were not (e.g. on a computer display). The low effort cost of accessing source materials through glancing at a spatial arrangement of documents reduced interference with the writing task.

> I like to have my sources all round me generally, so that I can, as I said, just for flow of ideas—I can have things to hand.

This is well illustrated in an example from CO, the contract lawyer who was writing an email reply to his client regarding some contract negotiations. The source materials that CO was using to construct the reply were the email exchange up to that point and the contract, both of which he had on-line. He printed out both these documents and arranged their individual pages over the desk such that he could view all the pages concurrently. The fact that a choice between electronic and paper versions of the source materials was available to CO for this purpose makes explicit the importance of the material characteristics of the source documents.

Being able to see multiple documents concurrently was also important in terms of being able to physically point at the source documents or specific parts of the document. For example, when paraphrasing a piece of information from a source document or evaluating it with respect to what had already been written, pointing to the page was important as a frame of reference with which to orient visual attention to the correct points in the documents as the writer moves between source material and composition (see Figure 2). By not having the documents concurrently visible (as on the computer monitors of the participants), this behaviour is not possible.

While the physical layout of documents had these positive attributes, it is also important to bear in mind the constraints that this created. Some of the participants, for example, felt constrained by the limitations of the physical space—not having enough room to spread as many documents out as they would have wanted. On the one hand, this only further emphasizes the importance of spatial layout of documents in supporting writing from multiple sources and why it might be problematic for people to gain similar benefits from on-line documents. For example, not being able to view multiple documents simultaneously and the fact that electronic documents are more visually homogenous than paper documents caused difficulties in terms of trying to utilize spatial layout on-screen. On the other hand, it illustrates some of the difficulties of organizing large numbers of documents in the physical world that in some ways can be easier to manage on screen.

> Its a bit of both because I could then have the books on my desk but then I wouldn't be piling all my books on my desk 'cause I have shelves—then I can also spread my documents out a bit more... it's like you know when I was picking up different ones to look at them, it would be so much better if I had enough space to lay them all out so I can just glance and see how this connects to that and this pulls in that...But I can see how it could be very useful space wise—spatially to have everything electronically.

3.2.3. Dynamics of spatial layout. Related to the pre-structuring behaviour was the dynamics of the structuring behaviour observed throughout the writing task. The spatial organization of documents during the writing task was something that changed many times as different source documents became the focus of attention or as certain

tasks demanded. This kind of dynamic restructuring of the information space according to the immediate needs of the task took on a number of forms ranging from temporary arrangements to longer lasting arrangements. There were many instances of participants partially lifting up and replacing a document to allow quick glances at obscured documents without disrupting the overall holding pattern of the spatial layout that they had created. These temporary lifting and dropping actions would sometimes be done several times for one singular subtask. Examples include comparing and contrasting a piece of information from each of the two sources, and deciding whether a piece of information would fit well with the flow of the composition displayed on the computer screen. Participants would also completely lift documents off the table for closer inspection. Both hands might be used to hold two documents side by side. As we saw previously, a document might be lifted up and brought closer to the computer display on which the composition was being created, particularly when working with the minute details of the information. For example, at one point, the contract lawyer, CO, while composing an email by way of response, suggests an amendment to the contract he is reviewing. This suggested amendment is to insert a certain phrase in between some of the current wording in the contract. In order to accurately describe this in his response, he brings the contract document closer to his computer so that he can carry out some detailed inspection of the contract. The purposes of this inspection are: (a) to check exactly where the insertion point is; (b) to check whether his chosen wording fits in appropriately; (c) to describe the insertion point by copying out verbatim the phrases in the contract that delimit the insertion point.

More longer lasting re-arrangements would also occur when new documents became the primary source from which the writer was, for example, copying material or paraphrasing ideas, or simply as an inspiration for generating new content. A number of the participants also suggested that they would periodically tidy up the working space in order to get things clear in their mind.

> Its like space to think. I had got what I wanted for the time being and it was like clearing my mind.

As Hansen and Haas (1988) noted, the tangibility of the paper reference documents is an important factor in their dynamic arrangement. Two-handed manipulation allows physical reference documents to be easily arranged relative to each other and to the written composition. It is precisely these spatial and semantic relationships between source materials and the composition that is fundamental to the task of writing from multiple sources. In our observations, these dynamic spatial relationships were more difficult to create with electronic texts because of their lack of tangibility and because of the limited space within which to arrange them on the computer screen.

3.3. ANNOTATION AND MARK-UP OF SOURCE MATERIALS

When considering the use of source materials in support of writing, current theories generally characterize them primarily as information displays. That is, such theories tend to describe these supporting documents as information output devices which the writer simply views in order to extract information or to inspire ideas in relation to the composition. The noticing and evoking processes discussed in Flower's (1990*b*) model

of writing from multiple sources exemplify this. However, our data showed that this misrepresents what writers actually do with source documents. The participants in this study were much more interactive with these documents. They annotated and marked up the source documents during composition, particularly in the case of printouts of electronic documents and photocopied documents (books were considered more valuable or were shared resources which sometimes discouraged their annotation). These markings and annotations served a range of different purposes for the writers in our study both as they were being made and consequently in terms of how they are subsequently used. For example, when we think about the task of writing from multiple sources, we can characterize it as a complex interaction between what participants have already written in their compositions, information in the source materials and knowledge in their heads. The participants, as authors, are having to integrate various bits of information from disparate sources and display spaces to create new ideas, judge how these fit within the flow of already composed text and work out how best to translate these ideas and flow in accessible prose. Consider an example of this from the contract lawyer, CO seen in Figure 5. CO was composing a draft reply to an email suggesting amendments to a contract on the basis of queries within his client's email (of which he had a printout). The annotation on the contract printout, "As per schedule 1", was in response to a query in the email concerned with the wording of clause 1.2. "Schedule 1" referred to an extract from a second, earlier email (also in printed form) from his client on which a revised schedule 1 would be derived when CO was actually composing the draft reply. The annotation therefore drew together information across two printed emails, a printed contract, knowledge in the head of CO and the written composition. This annotation had to be subsequently reviewed when considering it in light of actually translating this into composed text.

This is clearly a complex cognitive activity that is actually only manageable by breaking the task down into subtasks. There are simply not enough cognitive resources
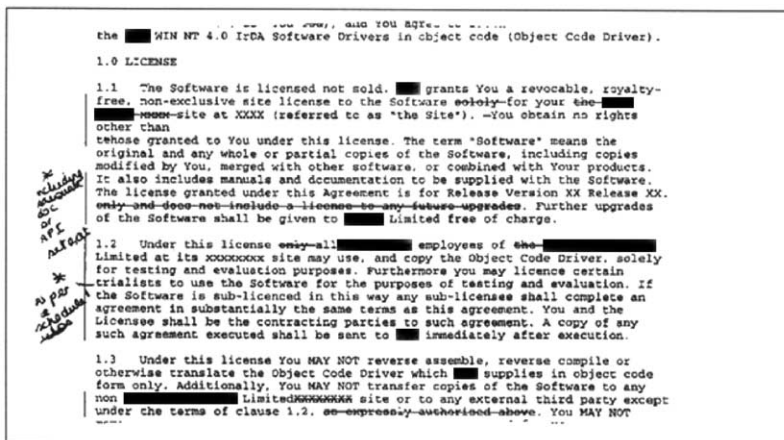

FIGURE 5. An example of annotation in the support of information integration and linking behaviour from participant CO. Masking has been used to cover confidential material in the contract and is not part of the original document.

available to carry out the integration process across source materials, maintain the outcome of this in working memory while reading the composition to feed into the translation processes that generate the appropriate prose. The material properties of the interaction with the source materials have an important impact on the way in which this activity can get broken down into manageable parts. First, the integration of material across source documents produces a new idea or information outcome that involved a complex set of interactions back and forth across the various source materials. Rather than having to maintain this new information outcome in working memory, the process of annotation allows the contents of working memory to be offloaded to the external representation. This prevents the information outcome from being lost when trying to perform the additional cognitive subtasks outlined due to bounded cognitive capabilities. This offloading process itself must not be cognitively demanding such that it threatens the loss of the outcome idea in the process. Our observations point to some crucial features of annotations and the material properties of the artefacts in support of them.

Within this task the annotations were, in Marshall's terms (1998a, b), personal, tacit and informal. This allowed them to be made quickly and with minimal disruption to the ongoing cognitive tasks they were supporting. As can be seen in Figure 5, the annotations were not stand alone in the way they represented the information. It was not possible for someone to ascertain the meaning without reference to the associated text in the source materials and to knowledge in the head of the participants. The annotations in this sense are cues that allow the outcome of the integration process to be somehow ''captured'' to be more fully reconstructed later. It is the informal and ''incomplete'' nature of these annotations that allows them to be made quickly in a way that is minimally disruptive to remembering the actual integration idea. In addition, the association of the ideas to specific contents in the source text across which meaning is distributed is not something that requires explicit cognitive articulation. Rather the associations are automatically embodied in the spatial juxtaposition of the annotation to the relevant portion of the text. This is again a way in which the cognitive effort was reduced by the physical features of interacting with the paper source material.

Sometimes these integration annotations involved linking and navigation between the documents across which ideas were distributed. While this link building and path making has been discussed to a certain extent by, for example, Marshall (1998a, b) there are nevertheless some further observations to be highlighted. First, the nature of this link building, while explicit was not complete. That is, the linking annotations were written in such a way that the author could reconstruct the link using knowledge in the head but not in a way that completely described the nature of the link.

> What I'd done is . . .because I know that the quote I am using from the green book provides me very useful entry point for me to refute the argument in the red book, I have to develop a sense of why this is a good entry point and all that is all in my notes. So that is why I was looking for that. Because I have got a summary of how, if you see < shows her annotations at the end of her previous draft > how I say I agree with Faulk and I have got ''see notes in grey book''. So it's all like my own signposting. I was telling myself to go and look at my notes in this book which is why I can then do this—to help me write this—what is still a very sort of compressed paragraph.

The "..see notes in grey book.." was a typical instance of these navigational links. The description of the source material as a "grey book" is completely understood by the participant. The participant also implicitly understands the specific whereabouts in the grey book to where the link was being made. These features do not need to be explicitly articulated for the purposes of the link making because their meaning is distributed across the internal and external representations and is reconstructed when necessary. It is the ability to distribute the information representation in this way that allows the annotation to be made quickly and succinctly and in such a way as to maintain the flow of the ongoing writing task. If such linking had to be made more precisely and completely, as in hypertext systems and electronic documents, it could potentially disrupt the flow of writing.

Participants described their thinking and integration behaviour as often reactive, with new thoughts and ideas being generated in an ongoing fashion during the writing process. Sometimes these ideas did not fit comfortably within the stream of what was currently being written but rather were ideas they thought would work better in other parts of the composition.

> That's something I find annoying about the screen. When you get an idea you can't jot it down. It's often related to another section. Quite often what will happen is I like to include quotes from books I've read and I'll think of one but it's nothing to do with what I'm writing I'll tend to go to paper.

Trying to remember these ideas while continuing with the current stream of writing requires mental resources. By recording these ideas in written form, the participants could externalize their thinking. This would free up the mental resources otherwise devoted to maintaining the new ideas in working memory, for thinking about the current writing stream. The quote suggests a preference for doing this on paper because trying to "jot" down ideas on-line was difficult. The implication of the term "jot" is that there is a need to record such information quickly and hastily so as not to minimize disruption to the current writing stream and that this is best achieved through scribbling on paper.

The micromobility of source documents was also important in relation to annotations. The angle on the horizontal surface at which a document is placed for reading was seen to be very different from the angle on the horizontal surface for writing annotations comfortably. As such, part of making an annotation involved an initial re-positioning of the source document and subsequent re-positioning to the appropriate reading angle once the annotation was complete. Paper documents, particularly printouts were more easily moveable across the horizontal surface supporting the flow of activities. This could typically be done one handed which was important for example when the other hand was engaged as a frame of reference on another source document across which material was being integrated.

The review of annotations was also a central feature of writing from multiple sources that needs to be considered from a materiality perspective. The primary feature of annotations in this regard is to reduce the perceptual complexity of the source material by making relevant points more salient against the backdrop of less important material on the page. Annotations disrupt the physical shape of paragraphs, lines and words to

achieve this result. This plays an important role in the noticing and evoking processes during composition, attracting writer's attention to specifically chosen parts of the text which are then considered in light of the content of the composition. This is a relatively well-established aspect of their role in this "annotation as reading" but there are more subtle behaviours that are supported by this ability to reduce the perceptual complexity of the information space that is a source text.

These behaviours refer to the multiple gaze shifts that occur for example when copying text between source materials and composition, when paraphrasing material from a source text, when comparing and contrasting across sources and when integrating material, etc. These behaviours involve dextrous cognitive manipulations using chunks of information picked up by perceptual processes during each gaze shift. Each shift of gaze requires the appropriate chunk of information to be relocated and each chunk may be revisited several times for each cognitive manipulation. This relocation process itself is cognitively costly. While approximate location of a particular chunk is gained from cues on the page such as page edges, corners and paragraph shapes etc, there is also a refinement process that takes place to locate the exact point. As such the composer may have to read a sentence or two in a paragraph to find the exact chunk of text that they need to process. This search refinement process on each gaze shift can be detrimental to the primary cognitive manipulations taking place with the information. As such efforts are made to support this refinement process using annotations to reduce the perceptual complexity providing a frame of reference to guide shifts of gaze. This type of frame of reference mechanism was particularly important as a hands-free mechanism during interleaved typing since participants would typically keep their hands poised at an appropriate position over the keyboard in preparation for typing (finding the position on the keyboard would be one more cognitive and perceptual overhead that is avoided by utilizing the spatial layout of the keyboard as an external resource for hand placement).

The need for the above types of annotation support is determined on the fly according to the immediate cognitive demands of the composition or reference behaviour. As such it must be viewed as very much interleaved with the composition process. A good example of this *in situ* tailoring of the information structure in a source document can be seen in Figure 6.

As can be seen in Figure 6, the information in the source material had been written such that a list of points had been written in continuous prose making the individual points difficult to visually locate. The participant wanted to paraphrase each of these in turn and so needed to perform some of the multi-gaze shift behaviour back and forth between the source material and composition document. To paraphrase each point in the paragraph she needed to locate the beginning of each chunk for each of the multiple gaze shifts she needed for each individual point. As she began this process, she realized that it was cognitively difficult because of the way the individual points were hidden within continuous prose. This was interfering with her ability to do the paraphrasing effectively. So in order to simplify the perceptual complexity of the language for this situation, she used marking of the source text to delineate the beginning of each point—effectively tailoring the structure of the information for her on-the-fly needs during composition. This offloaded the cognitive demands of the search refinement

Some of these are very similar to the demands detailed in the Geography A level version of Edwards et al.'s (1985) scale. Constructs 1 and 3 relate to the resources dimension of the scale of demands, and 7, 9 and 10 refer to abstraction. Numbers 4, 5, 6 and 8 may relate to the scale of complexity and 2 and 11 to strategy.

Each sub-question, or chunk, of each question was then rated on a five point scale according to how demanding it was in terms of each of the constructs. The ratings were analysed using principle components analysis, and four factors emerged, suggesting that the constructs were based on four different types of demand. One factor consisted of constructs relating to resources, another included constructs relating to structure, such as number 8, the third consisted of constructs such as abstraction and time, and the fourth included most of the other constructs and could be labelled complexity. The factor weightings are detailed in the table below.
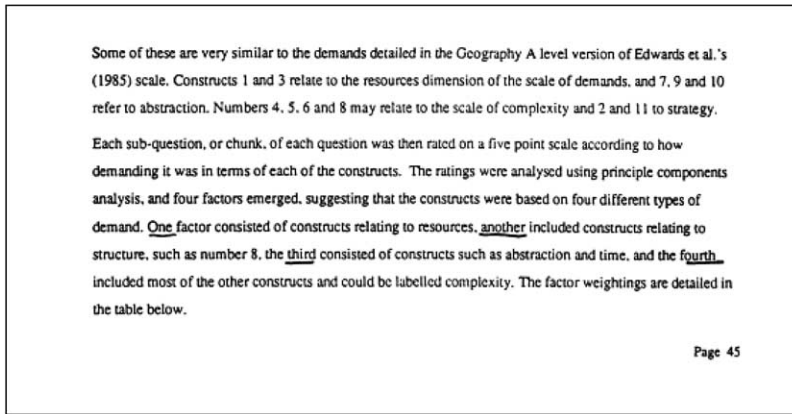
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FIGURE 6. An example of how annotation was used to impose a more appropriate structure on the information in a paper source document than was seen in the original prose structure.

process to the external representation and allowed the limited cognitive resources to focus on the primary task of paraphrasing.

> Oh yeah. On the geography A level source I was looking for the factors…yeah looking factors identified in the repertory grid interviews and I just had trouble finding in the text where that was and when I did find it I underlined it. One factor, and another and a third and a fourth.

> Int: Why were you doing that [marking out the points] as opposed to pointing like you did the last time?

> "Because the last time I knew that 1 was followed by 2 was followed by 3 whereas as here I found them all first and then wrote them down rather than…because it was just a bit like—She didn't say…she doesn't say "1,2,3,4" she says "1, another, 3,4". It's hard to keep up innit when people do things like that." SH

3.4. USE OF PAPER AND ELECTRONIC VERSIONS OF THE SAME DOCUMENT

An interesting feature of many of the writers in the study was their concurrent use of paper printouts and electronic versions of the same document in writing from multiple sources. It explicitly demonstrates awareness, on the part of the writers, of how the unique physical characteristics of the document media support different aspects of the writing and reading tasks.

An example of this can be found in the protocol of SHVY. SHVY was a student studying English and American literature. An important feature of her work and thesis was the use of quotations, in particular from primary source materials. Because of this emphasis, SHVY had created a large "database" full of important quotations in which she had arranged the quotations in a table format according to topic and source. When writing, she would come to a point where she felt a quote was necessary either as evidence for a point she had just made or as a lead into a new point. The purpose of the "database" was to help her locate and incorporate quotations efficiently while writing so as to minimize disruption of the creative flow of ideas. The important point was that

the database was stored not only on her laptop but that there was also a printout of it in a bound file propped on a reading stand on her desk. This dual-medium representation of the database highlights common misconceptions that on-line search is universally beneficial. What it indicates is that both the paper and electronic versions of the document supported different types of search. For specific quotations, she was able to use the keyword search facilities of the electronic version to locate the information she needed. However, it was often the case that she was unable to be that specific. In these circumstances, she would have a general memory that there was something relevant but would not be able to recall and specify a particular quotation.

> I think there's a little bit of free play and inspiration that comes along, I think. I don't…I definitely…I mean I have the reservoir of quotations there but I usually have to look through them and then mark which ones I want. I can't just pull it out, you know. I know certain general areas where I know there is something I want but I can't pick out the exact quote out of my memory so I usually go through these notes and think "Oh that's good, that's good, that's good" and then compile them and then write around that. That's usually the way I do it.

This implicit awareness of quotation material meant that the search for the right quote could not make use of the search facilities of the electronic version of the database. Her search therefore took place in the paper version where she could browse through a selection of quotations in the general topic area. In this non-specific search, she was looking for a quotation that best led on from her previous writing and that also would provide the necessary kind of inspiration for how to continue with the composition. The paper version of the database provided a number of important characteristics that helped her in this process. With the paper version, she was able to view a larger volume of information than was possible for her to see on the small screen of her laptop. This helped her to scan the information quickly and view different quotations in the context of each other. She was able to flick through the paper pages of the database and move back and forth easily within the document to review candidate quotations.

> I usually print out a copy just because again the… I can read it on the screen but I tend not to. One long continuous thing of text… it's just hard to keep your attention span.

Such flexible movement in the electronic version of the document was not possible so it was less suitable for this freeform, non-specific search task. The other important feature of the paper version was that it occupied a separate space and so was visible concurrently with the written composition. In contrast, the electronic version was in a separate window on the laptop and so could not be viewed simultaneously with the written composition. This was important, again because of the nature of the information being sought. Because SHVY did not have a specific quote in mind, it was necessary in these types of situations for her to understand how candidate quotations would fit within the context of the composition. This required the movement of visual attention back and forth between the quotations in the paper database and the written composition on the laptop to see how it flowed from what had been written and how it inspired appropriate continuation. This was something that was done through shifts of gaze while using the paper database but not so with the electronic version that was not concurrently visible. Once the potential candidate was chosen from the paper

database, it was easily located in the electronic one and simply pasted from the database into the written composition. This was useful in that it allowed the quotation to be incorporated in a time-efficient manner maintaining the creative flow of her writing process. Once the quotation had been pasted in, SHVY would then read the written composition to further check it in its actual context and also to interpret it within the context to inspire the next direction in the writing.

> The basic idea was there. Yeah, I mean the basic idea that there were many different levels that Emerson was looking at—that was there but the boldness….I guess it is in the background always like it…but it's a question of when is the right time to bring it into the argument. And it just seemed like after reading that, especially because it was finishing up on that note it seemed like the most salient aspect.. Because, I mean this whole quote is about materialism and idealism, period, so I know that. But then the question is now I'm thinking "OK how can I make some interesting and important points, sub-points, about how materialism and idealism work in Emerson's system more specifically, and that I do leave…that is not all planned out in the beginning. That is more, as I say, like based in what I am reading at the time in theses quotes and I try to keep that as part of the writing process that I have time to think about it and then write rather than having it all planned out.

> INT: "Why did you read it on screen and not on your notes?"

> That's a good question—after saying how much easier it is. Maybe because I was reading…I wasn't just reading the quote but I was reading this too, like to see how I'd set it up. Because, I mean I wouldn't have wanted just to read that without seeing the context in which I framed it so… Yeah. But I did read it originally on paper. I read it originally on the paper, said "Yeah this is good" but then once it was here I wanted to make sure it was coherent with the introduction.

While in this instance the quotation incorporated was accepted by her in its form and position there were also instances where the chosen quotation did not work as she anticipated when viewing it in the context of the document being composed. As such she would look for a more suitable quotation. This illustrates the importance of the low time and effort costs associated with copying information from the electronic version of the database since they support a "try it and see" type approach that suits the uncertainties associated with the quotation selection. It can be seen, then, how the paper and electronic versions of the same document can be used in a complementary manner.

Another illustration of this use of paper and electronic versions of the same document can be seen in the protocol of GS, a student of architectural philosophy in the process of writing a chapter for her thesis. GS was essentially working from 20 pages of structured notes. These notes were basically going to act as a kind of skeleton from which the more complete chapter would be constructed—what she called an "accumulative" style of writing. The notes consisted of sections that were complete and others that were more in the form of unfinished sentences. She would build the chapter up by copying sections from this file into a new file, removing bits and adding bits, and restructuring the order of the basic arguments as necessary to create a more complete and coherent version of the chapter. In order to carry out this process, she had a printout of the structured notes file and an electronic version of the file. The paper version of the file was important for the restructuring processes in that it helped her

"think". She was better able to understand the structure of the information (cf. Haas "sense of text") and see how it needed to be restructured to read more fluidly.

> Because the word processor doesn't help me to think. That's the first thing. I use it mainly as a tool, in a sense. I mean it's very—it's faster than me when you have to paste and copy. But I don't like, for example the whole idea. . .OK you can get the kind of smaller version here, like, you know, you can see the whole page but the problem is that the way I think and I reason I need to see, for example, if I am thinking about the structure of the little subchapter I need to have a printout to see the sequence of the sentences while. . .and just to have it like almost on one side—it's not possible on a computer because you are dealing with a part of the text. It's also, I think, that I can concentrate more on the printout or rather like, comparing the printout or. . .I should say, I mean the major part of my thinking about the structure I am doing looking at the printout of my file while the, lets say cutting, pasting, restructuring—that's why I am using the computer. But I tend kind of to stop thinking when I am doing that.

The paper document allowed her to see a lot of information at once by being spread out in space in a way not possible with the electronic version. In this way, one section of the chapter could be viewed in relation to another, to assess the sequencing of the sentences and arguments. The paper allowed easy movement of visual attention back and forth within the document to see whether certain bits of information would be better in another part of the document or removed or whether certain information needed to be added to improve the flow. The quick movement back and forth afforded by the paper version allowed the participant to take advantage of her familiarity with the document content. This familiarity meant that only the briefest of glances was necessary to establish the structural information required to make the decisions. The participant was simply recognizing sections of the text rather than having to completely read them.

> INT: "Why is it that you have a little brief glance?"
>
> Well because I don't really read it because I know it in a sense that I kind of read a couple of you know. . . I'm trying to catch, you know, kind of the most important words which are there. Because it's not, as I am saying, it's not about writing full sentences but it's about you know. . . I mean I know what the whole argument should be about. So at that stage of my work I don't need to concentrate on any kind of detailed information. The most important thing is the overall structure. So that is why you probably, you wont see me kind of carefully reading the text and slowly reading the text.

Again, this kind of decision-making often involved referring back to the written composition on the computer in order to get a sense of prospective changes in relation to what had been written. This required the concurrent visualization of the source material and written document that paper provided.

The paper document also supported this part of the writing process through the use of annotations. Sections were crossed out or relocated by annotating the paper document, which meant that they would not be included in the new written composition. However, they were not to be removed from the electronic version of the notes in case they needed to be used in the future. So the paper version acted as a temporary record of changes made so that GS could see what she had implemented. This was because she would not be able to complete the restructuring in one sitting and

so needed to have a record of the changes she has made so as not to create conflicting changes in future writing sessions.

> So that is why, I mean for example, this printout which I have like…I find it really helpful in the sense that I have got…in one file I have a printout of everything which I think is important for this particular chapter. And it's also…I always put in a little note, in a sense whenever I change this pile I always try not to be lost in this thing even though it's only referential and try to put a little note where, you know how you will change.

> INT: "And why is that important—so that you don't revisit them or put something in elsewhere or what?"

> No. This for example, these little notes are important only for today in a sense that, I mean I might need it later but I think that now the major part of my work is already here…that some of the parts are not pasted into this version which is going to be final so I have to mark those who are not, I mean kind of…they are not important because…I wont be able to finish, for example, 20 pages written within 1 day so I keep it for a kind of reference."

Interleaved with this thinking and restructuring using the paper document, the changes were implemented by copying and pasting sections from the electronic version into a new electronic file, and restructuring them as had been decided. Again, it was the flexibility of the electronic version for this aspect of the task that complemented the use of the paper version. The participant thus saw the laptop as merely the tool for implementing the conceptual work that was being done on paper.

4. Discussion

In this paper, we have begun to explore the task of writing while reading from multiple source materials. While the paper has built on earlier cognitive theories of writing from multiple sources (e.g. Flower, 1990*a, b*), it has, by contrast, taken as a primary focus the role of material artefacts in shaping the behaviours and cognitive activities that comprise such a hybrid task. By looking at the role of these external resources in this particular task context, it has been possible to demonstrate how cognitive processes are distributed across both internal and external representations in such a way that cannot be encompassed by cognitive explanations that rely purely on internal representations alone. Cognitive processes such as noticing, evoking, organizing and translating have all been seen to be highly dependent upon the way that people can manipulate and interact with external representations, which in turn is dependent upon a particular representation's material characteristics. In this respect, the work in this paper builds on the work and philosophies of writing theorists such as Haas (1996) and Neuwirth and Kaufer (1989) that have made explicit attempts to incorporate thinking about external artefacts and resources into their theories and understanding of writing and synthesis writing. In particular, this paper has been able to further the understanding in this area by paying particular attention to the material characteristics of the source materials themselves and their role within this special, but not uncommon type of writing task. In sum, these can be categorized into four key areas.

4.1. SHIFTS OF ATTENTION ACROSS SOURCE MATERIALS AND COMPOSITION DOCUMENT

The task of writing from multiple sources was characterized by frequent shifts of attention across source documents and composition document using shifts of gaze and larger body movements around particular information artefacts. These shifts of attention were performed, for example, to integrate knowledge in the head with information from disparate sources, to transfer information from source documents to the composition, and to consider information from sources in the context of the composition flow. Often, these glances were not for the purpose of complete re-reading of information but rather were based on recognizing cues in previously read and annotated pieces of text to more detailed knowledge in the head of the writer. As such, the nature of these attentional shifts were of very small orders of time magnitude and involved frequent back and forth movements between the same information in support of a single unit of cognitive activity. The use of multiple display surfaces was important in this respect in allowing concurrent visualization of composition and source documents that supported the quick moves necessary across multiple documents. This reduced the cognitive interference that would be caused by having to explicitly articulate which document to visualize for each shift of attention. Fixity of information with respect to page boundaries on paper documents was important in quickly guiding visual glances back and forth to the correct places across multiple documents. Concurrent visualization of documents also allowed physical pointing to be used as frames of reference for guiding attention.

4.2. SPATIAL LAYOUT

The arrangement of source documents in space in relation to each other and in relation to the composition display surface was an important feature of participants' strategies during their writing task. This was both in the preparation for particular subtasks as well as ongoing micro-movements and dynamic arrangements in support of the *in situ* demands of the task. Such arrangements of the physical space were used to reflect task structures in the writers' heads and to help in the organization of material for the composition. These arrangements involved the chunking together of physical pages or documents as well as physical juxtaposition in support of some of the attentional shift behaviour discussed previously. Documents and pages would be brought to and from the peripheral display area to the central area of attentional focus. Documents were re-arranged on the desk surface as well as being picked up for closer inspection or to quickly reveal hidden pages underneath. These micro-arrangements often involved two-handed manipulation and also involved the concurrent placement/manipulation of multiple documents in parallel. This included, for example, relative placement of documents, navigating through one document while pointing to maintain a place in another document and shifting documents from a position comfortable for reading to one comfortable for annotating.

4.3. ANNOTATION

The use of multiple sources when writing a composition is more than simply for the display of information for the purposes of reference. These artefacts were used as a

place to make annotations in a way that is interleaved with ongoing writing. Annotations help engage the writer with the source materials supporting a whole range of activities such as navigation, linking information across source materials and between source materials and composition, structuring thoughts, offloading new idea threads to be followed later on in the composition and offloading the results of tasks taking place across multiple documents. The annotations used during these tasks were not stand-alone but rather were pointers to knowledge remembered, or represented internally, by the author. This has some important consequences. First, the use of annotations during these types of tasks is about maintaining a cognitive flow in terms of interacting with the source materials and thinking about the composition flow in the writing. Using a free-flowing unconstrained set of marks on top of existing source materials is important in allowing low-cost recording of pointers to more elaborate knowledge in the head without causing interference with the information processing they are pointing to. Because the meaning in annotations is distributed across internal and external representations, more explicit recoding of certain meanings or links is less necessary. Second, reading annotations is about reconstructing earlier cognitive states. Annotations in themselves are not sufficient to support this process but rather it is dependent upon some of the earlier issues discussed in relation to attentional shifts and features of spatial layout. It is the interaction of these issues that gives annotations much of their value.

4.4. CONCURRENT USE OF PAPER AND ELECTRONIC VERSIONS OF A DOCUMENT

Writers from multiple sources often use different media formats of the same document concurrently to provide a complementary set of affordances for interacting with and using information from multiple sources. For example, paper supported the quick flexible navigation of a document for more non-specific information search behaviours due to its tangibility and fixity of information with respect to a page. The electronic documents used supported more specific search behaviours and the ability to transfer information from one document to another through copying and pasting to see how it worked within the composition.

4.4.1. Technology implications: from PCs to ebooks. With these findings in mind, we can begin to examine why such an analysis has important implications for understanding the design, use and adoption of emerging technologies in relation to these kinds of hybrid reading-to-write tasks that typify many everyday writing behaviours. We will do this by focussing in particular on a few key technologies such as ebooks† and PCs and use the understanding gained from the distributed cognition

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†For the purposes of this discussion, an ebook is considered a portable, tablet-like device designed to display electronic documents in full-page layout mode for the primary purpose of reading. Usually built with a backlit touch-sensitive LCD display, the ebook provides the reader with the capacity to read, store and manage online source materials. The interactive elements of the device, normally controlled using a stylus, often simulate book-like qualities, with dedicated buttons for page-turning, and book-marking and annotation features available. Some specific examples of this technology category include the SoftBook Reader and Nuvomedia RocketBook.

analysis to assess some of the potential benefits and shortcomings in relation to existing artefacts used during these tasks such as paper.

First, let us consider the issue of shifting attention across composition and multiple source documents. On a PC with a typical single monitor configuration, the available display space is dominated by the composition window. While on a PC screen it is possible to display source materials such as PDFs from a digital library, it is very difficult to present these concurrently with the composition document. As such the quick glance shifts of attention are just not possible. To move between these different documents purely on a single monitor PC would require a more serial presentation of information to be integrated, compared or copied. As we saw from the order of time magnitude of the attention shifts and the frequency of movement back and forth between documents in support of a single unit of cognitive activity, serial presentation of documents is not well suited to support these kinds of activities. Multi-screen PCs are gradually becoming more prevalent within organizations (e.g. Grudin, 2001). While these allow the concurrent presentation of a source document and composition document that can be of some benefit there are still certain drawbacks. One of these is the fact that input and control of these separate spaces on a multi-screen PC remains serial. Therefore, it is difficult for any navigation activity to take place in preparation for these attentional shifts without disrupting the ongoing flow of writing. The second issue concerns the use of frames of reference to guide visual attention. Unlike paper, which has fixity of information with respect to page boundaries, because PC-based documents use navigation techniques such as scrolling, there is a dynamic relationship between information and the primary frames of reference—the window boundaries. There is evidence to show that this interferes with the development of incidental memory for spatial location of text that could be used to guide visual attention (e.g. Rothkopf, 1971; O'Hara *et al.*, 1999).

Ebooks potentially overcome some of these problems associated with the PC. If an ebook were to be used in conjunction with a PC-based word processing capability, it would provide the additional display space to concurrently present a view of one source document. Because it is a separate device it has the advantage over the PC of having independent control over input and navigation activities. As such the navigation and control activities in preparation for attentional shifts can take place in parallel with work on the composition document. In this respect, an ebook offers some of the benefits seen with the use of paper by participants in the study. Ebooks have also typically adopted the model of paper by presenting fixed pages of information thereby providing appropriate frames of reference for aiding the spatial memory for information on a page necessary for shifts of gaze.

However, like PCs, ebooks are still limited in their ability to present multiple documents in the way that paper was used by participants in the study. This critique applies also to the concurrent presentation of multiple pages from the same document that was also seen in the study. Visualization techniques based on toggling between different documents or pages provides only some of the solution. Without concurrent presentation of material, it is not possible to physically point across multiple source materials in support of these shifts of gaze. In addition, toggling requires a document or page to be intentionally brought to the surface. This characteristic will reduce some of

the more spontaneous noticing and evoking of material in relation to the composition document that can occur by having more continual visual access to documents in peripheral display space seen with paper.

Related to this are the findings concerning spatial layout of source materials. If we consider the PC, the level of structuring of source materials adopted by participants with paper-based source materials would not be possible in the same way. While windows can be tiled and laid out in the display space of the screen, there is very little room to be able to do so effectively with multiple documents. Windows and documents cannot be grouped together and moved around as a chunk of information. There is also not the same notion of peripheral and focal attention in relation to the arrangement of source materials. Even on multi-monitor PCs there is limited space to think about peripheral and focal presentation of source documents. Certain visualization techniques on PCs may offer some support here such as focus and context techniques (e.g. Furnas, 1986; Robertson & Mackinlay, 1993). These provide an overview of the whole information space in depleted detail while focus of attention is presented at much higher detail. Indeed, such techniques may allow the management of even larger information spaces that are not practical in the physical world of paper. But ultimately, they lack the same level of tangibility that the paper source materials offer in support of the spatial arrangement characteristics of these hybrid tasks. This is particularly important with respect to the ongoing dynamic arrangement of source documents in space in response to the *in situ* demands of composition. Indeed, it is the micro shifts of source materials that were seen with paper that are very difficult to support in the electronic world. By this, we mean that the ability to manipulate the angles of documents for reading versus writing, bringing documents closer for inspection or to compare them or using two hands to arrange documents or pages next to each other are all features that have no simple counterpart in the electronic world of the PC and ebooks. While ebooks offer a certain ability to be moved around in space, they are not primarily designed for the level of micromobility that the paper affords. An ebook does not "slide" around a table in the same way that a paper document does and therefore hinders the subtle but important positional shifts. Additionally, with respect to the juxtaposition of source materials, one can imagine multiple ebooks offering some flexibility over arrangement in space but it is likely that this will ultimately be too cumbersome and expensive a solution in relation to paper.

The role of annotations in reading and writing has been extensively discussed by numerous authors as well as their implications for technology design. Yet if we consider many everyday PC-based document applications there is still typically a limited model of annotation. Highlighting and type-written text annotations are generally available but these do not approach the sophisticated level of affordances seen in the fluid free-form markings on paper-based source materials. In addition, if we consider the input mechanisms that need to be used for these annotations they are clearly ill suited to the task. For example, they cannot be performed in conjunction with control and input of the composition, which makes the interleaving of reading, annotating and writing somewhat problematic. The ubiquitous mouse as an input device is also not designed to effectively support free-form markings on text and, while there are more purpose-made input devices such as the stylus, these still remain relatively rare in PC usage.

Ebooks of course have made considerable improvements over the PC in this domain by offering stylus based free-form annotation facilities (e.g. Schillit, Golovchinsky & Price, 1998). Ebooks also act as a separate display space from the composition document and thus afford parallel input to composition document and source documents allowing more effective interleaving of reading, annotation and composition behaviours. They also offer some interesting new functionality over paper documents in this domain. For example, they provide the possibility to search for particular annotations and markings. Perhaps more intriguingly, certain prototype ebooks build on an important aspect of annotation functionality, namely the linking of ideas across source documents. Xlibris (Schillit *et al.*, 1998) allows explicit hyperlinks to be made between different source documents through the use of free-form annotation as well as generating a suggested set of hyperlinks to other relevant documents in the ebook or Internet-based document repository based on the interests of the reader as indicated by the annotations. While these offer interesting new possibilities for working with and navigating around the source document space for the purposes of composition, it is important to recognize that this kind of hyperlinking is different from the linking behaviour that was taking place with paper documents in the study. As was illustrated in the findings, this linking across documents is more than just a pointer to a relevant piece of context in another document. Annotations on paper are also pointers to knowledge in the head based around the linked pieces of content in different documents. When reviewing these annotations, this knowledge needs to be reconstructed and it is this process that requires additional quick glancing, back and forth movements between the linked pieces of information. This aspect is supported by paper over ebooks because of the affordances discussed previously in relation to spatial layout and attentional shifts. Without supporting this additional behaviour in ebooks the role of annotations is therefore altered.

Finally, let us consider the implications of the findings that participants were using paper and electronic versions of the same document simultaneously to achieve certain goals during the task of writing from multiple sources. While the different affordances of paper and electronic documents have received considerable attention from certain authors (e.g. Haas, 1996; O'Hara & Sellen, 1997; Harper & Sellen, 2001), there are nevertheless novel implications to be drawn within this particular context of writing from multiple sources. For example, the simultaneous use of different media formats of the same document and the way in which people choose to distribute particular activities across different representations of the same information is a new finding. The complementarity of these different media formats and the details of the activity distribution across representations is an important tool for thinking about new technologies. By understanding how people have chosen to distribute tasks across media, we can identify interesting ways in which technologies such as ebooks and certain PC software actually violate the demonstrated basis for this distribution—focussing too much on trying to emulate certain beneficial affordances of paper at the expense of particular digital affordances for which they might be better suited. Consider again the example of electronic books. These do of course offer additional search affordances which therefore play to the strengths of the digital medium. However, they violate one of the other complementary features of the electronic documents seen in this study, namely the transfer of information from source to composition. Because an

ebook works as a separate device from the typical composition tool that is the PC word processor, ebooks do not support the easy copying and pasting of information from source to composition. In designing ebooks, it may be worth considering how they could work in this scenario in conjunction with the PC. The point we are trying to make here is that it may be more important for these digital alternatives to focus more on the unique affordances that they can offer over paper rather than over investing effort into trying to emulate the affordances of paper for which they are likely to remain inferior.

An example of a more complementary approach can be seen in Camworks (Newman, Dance, Taylor, Taylor, Taylor & Aldhous 1999; Taylor *et al.*, 1999), an over-the-desk camera-based paper scanning technology. This technology allows paper documents to be used in the beneficial ways shown in this study as well as allowing text to be copied from paper, converted into ASCII text using optical character recognition and subsequently pasted into the electronic composition or used for text searching. This technology provides an example of an important design implication, namely the linking between paper and electronic versions of the same document in a way that respects rather than violates the mutual affordances of each.

In sum, what we hoped to have done in this paper is extend our understanding of the particular hybrid task of writing from multiple source materials beyond the existing cognitive accounts of this task and earlier explorations of the role of external representations in such tasks. The type of analysis presented here that explicitly considers how cognitive structures and behaviours are distributed across internal and external representations can usefully contribute to the continued theoretical development of this area. In addition, by carefully considering the particular characteristics of the material artefacts and the possibilities for interaction that they afford, we have shown, by critical analysis of some key example technologies, as to how it is possible to use this understanding to inform the design of emerging technologies and to make judgements about their likely adoption for the kinds of tasks studied here.

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