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ABSTRACT

A study examined whether word processing amplifies writing performance and whether it restructures the process of writing. Sixteen college students wrote a short essay in a single session on either a word processor or in longhand. The quality of the essays was assessed by trained judges who rated their content and style. Text analysis methods were also employed to corroborate the subjective ratings. Writing fluency was measured in terms of words produced per minute of composing time. Changes in the organization of cognitive processing were studied by measuring the degree of cognitive effort and processing time associated with specific writing processes. Findings suggested that word processing restructured writing processes, but failed to amplify writing performance. Most importantly, results indicated that the pattern of allocating cognitive effort to writing processes interacted with the type of writing tool. Whereas effort was distributed about equally to planning, translating, and reviewing when writing longhand, a different pattern was seen on the word processor. Planning and reviewing consumed the most effort, and translating the least. Processing time, in contrast to cognitive effort, failed to show any interaction between writing tool and process. (Nine figures of data are included; 18 references are attached.) (KEH)

Cognitive Tools and Thinking Performance:

The Case of Word Processors and Writing

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Word processing is a widely used cognitive tool for composing written documents. Although there is much interest in the design of cognitive tools and in understanding how such tools affect thinking, surprisingly little research has examined adult writers using word processors. The study I report today explored whether word processing amplifies writing performance and whether it restructures the process of writing.

Jerome Bruner (1966) was one of the first to propose that cognitive technologies, such as written languages, act as amplifiers of mental functioning. On the surface computers appear to be particularly powerful amplifiers of our natural abilities, allowing us to do tasks more effectively and efficiently than normal. For example, John Seely Brown (1985) described how a computer learning environment amplifies a student's ability to learn algebra relative to traditional methods.

As an alternative view, Roy Pea (1985) proposed that computers do not merely amplify our mental functioning. Rather, they change the tasks we do by reorganizing our mental processes. Pea (1985) argued that the changes in mental functioning that take place when computers restructure the cognitive processes used to carry out tasks is the key to understanding the effects of cognitive tools.

Rationale and Predictions

In the present study I explored these ideas empirically for a commonly used cognitive tool, the word processor. Adult students wrote a short essay in a single session on either a word processor or in longhand. The quality of the essays was assessed by trained judges who rated their content and style. Text analysis methods were also employed to corroborate the subjective ratings. Writing fluency was measured in term of words produced per minute of composing time (WPM). Changes in the organization of cognitive processing were studied by measuring the degree of cognitive effort and processing time associated with specific writing processes.

Three processes are distinguished (Flower & Hayes, 1980). Planning refers to creating ideas, organizing ideas, and setting goals to achieve during composition, such as choosing the appropriate tone for a given audience. Translating ideas into text refers to sentence generation, including all semantic, syntactic, and pragmatic operations. Finally, reviewing refers to reading the evolving text, evaluating the text or plans for text, and editing errors. Planning, translating, and reviewing occur repetitively during prewriting, first draft, and subsequent draft phases of document development.

Processing time-- the time spent attending to a particular process-- and cognitive effort-- the degree of attentional capacity momentarily allocated to a process-- were examined. While the writer composed, a tone occurred on a random basis. On hearing the tone, the writer said "Stop" into a microphone and the reaction time (RT) was recorded. Then, the writer pressed one of four buttons labeled planning, translating, reviewing, and unrelated based on what he or she was thinking about at the moment the tone occurred. Participants were trained to identify their thoughts as examples of these four categories. The unrelated category included all thoughts that did not illustrate planning, translating, or reviewing. Increases in RT above single task, baseline RT reflected the degree of cognitive effort devoted to the particular writing process reported. The percentage of times that the writer reported each type of process provided an estimate of processing time.

The amplification hypothesis predicts that writing on a computer should be more fluent and the resulting document should be of higher quality compared with writing by hand. Previous research on whether word processors amplify writing performance is equivocal (Kellogg, 1989). The restructuring hypothesis, on the other hand, predicts that either processing time, cognitive effort, or both should be differentially allocated to the writing processes across computer and longhand conditions. Previous evidence is thin to say the least and only weakly suggests the shape that restructuring might take. Planning appears to be harder on a computer than in longhand (Bridwell-Bowles, Johnson, Brehe, 1987), whereas translating and in some ways reviewing seem easier on a word processor (Daiute, 1985; Zinsser, 1983). Apparently, no previous study has actually measured processing time and cognitive effort while writers compose on computers.

College students wrote essays on one of two topics in either the computer or longhand condition ($n = 16$). The procedure was too involved to describe in detail here, but it included training students in the computer condition to use a simple word processing program, The IBM Writing Assistant on an IBM PC. This was selected because the software is very easy to learn and use and the students were already familiar with basic word processing on IBM PCs. All participants were trained in directed retrospection and baseline RTs were collected. Several questionnaires were administered after a 30 minute composing session, and permission was obtained to secure the student's standardized test scores from the registrar.

Results

Performance Measures

The first group of results concern the quality of the essays written. The significance level was set at $p < .05$ in all statistical tests. Shown in Figure 1 is the mean stylistic ratings obtained in the two conditions. The judges showed a statistically reliable degree of agreement for these ratings (r = .66 for content and r = .71 for style). Running counter to the amplification hypothesis, the style ratings were significantly poorer in the computer condition than in the longhand condition, $F(1,30) = 5.95$. Although the same trend occurred in the content ratings, as shown in Figure 2, the difference was nonsignificant. The content data were more variable within conditions than were the style ratings.

Thus, composing on a word processor not only failed to improve the quality of writing, it actually decreased the stylistic quality based on subjective ratings. To shed light on why the computer generated essays were judged more harshly than those that were handwritten, several text analyses were undertaken.

The mean words per sentence is a simple text measure that relates to quality ratings (Reed, in press). Highly rated documents are comprised of sentences that average between 8 and 23 words per sentence. Too few words on average suggests undeveloped sentences and too many indicates overloaded sentences. Here both longhand (M = 20.4) and computer (M = 21.4) documents fell at the high end of this range, with no reliable difference between them.

Given that the conditions differed significantly in style, spelling errors and grammatical errors were of obvious interest. Grammatical errors included run-on sentences, subject-verb disagreements, wrong pronouns, and noun-modifier disagreements. The longhand condition averaged only 2.2 grammatical errors and the computer condition averaged 2.5, not a reliable difference. In contrast, the computer and longhand conditions differed significantly in spelling errors as can be seen in Figure 3, $F(1,30) = 6.26$. Over twice as many spelling errors were found in the computer condition as in the longhand condition. Inspection of these errors suggested that many of those found in the computer condition were typographical errors (e.g., hte). The higher incidence of such errors in the computer condition may explain the poorer style ratings assigned by the judges, who were asked to consider spelling.

Another reason for the poorer style ratings may have been that the essays written on word processors lacked cohesion. In extreme cases, content ratings would probably also be affected by poor cohesion. Cohesion was studied by analyzing the sentence to sentence connectedness of each document. Halliday and Hasen (1976) have identified coherence ties between sentences that create cohesive text. The presence of such ties distinguishes essays holistically rated by judges to be of high versus low quality (Witte & Faigley, 1981). Following the procedures of McCutchen (1986) three main types of connections were tallied: local, remote, and failed.

Local connections are those between adjacent sentences. A sentence that is linked not only to the immediately preceding sentence but also to an earlier sentence is scored as local. Remote connections are those between one sentence and a previous one, but not the immediately preceding sentence. Failed connections occur when no connection is apparent or when the connection is too vague (e.g., ambiguous pronominal references). They violate the Given-New contract of cohesive discourse in that they fail in some way to establish a link with given information and then provide new information.

Figure 4 shows the mean number of local, remote, and failed connections. The low number of failed ties suggests that the essays displayed a high degree of cohesiveness. This was achieved primarily through establishing extensive local ties. An ANOVA on the data indicated a significant main effect type of tie $F(2;60) = 204.10$, but no effect of writing tool and no interaction.

The local ties were further analyzed to see if the specific way that a connection was made differed between the longhand and computer conditions. For instance, reference ties, which employ an exact lexical repetition or pronominal anaphora, can be distinguished from lexical ties, which involve semantic overlap or paraphrasing instead of repetition. Following McCutchen (1976), the other ties analyzed were inference, relational, conjunctive, and complex-syntactic. Briefly, the results showed that reference and conjunctive ties were used more frequently than other types. But the pattern of results was the same for those writing on a word processor versus in longhand.

The length of the essays was slightly shorter in the computer (M = 296.7) than in the longhand condition (M = 340.2), but the difference was nonsignificant. Expressing these data in terms of fluency of language production, writers using the word processor composed about 10 WPM while those writing longhand produced 11 WPM.

In sum, there was no indication that the word processor amplified writing performance, despite a comprehensive search for positive evidence. In fact using the computer slightly worsened spelling and style relative to longhand.

Process Changes

Now I turn to whether word processing restructures the process of writing. First, consider the cognitive effort index of attentional allocation. An increase in RT over baseline reflects the cognitive effort demanded by writing. The data are presented in Figure 5. An ANOVA revealed a main effect of process, $F(2,60) = 4.14$, and more importantly, an interaction of process and writing tool, $F(2,60) = 3.40$. When writing in longhand, planning, translating, and reviewing required approximately the same degree of cognitive effort in this task. In contrast, translating required less effort than planning and reviewing when the writers composed with a word processor. The simple effect of process in the computer condition was statistically reliable, $F(2.60) = 7.04$. Thus, the type of writing tool clearly dictated the allocation of cognitive effort to writing processes.

The other measure of attention, processing time, is presented in Figure 6. Processing time was estimated by computing the percentage of times that the writer reported each process during the first, second, and third 10 minutes of writing. The students allocated over half of their processing time to translating and about equal amounts to planning and reviewing. Planning time decreased slightly across phases, whereas reviewing time increased. An ANOVA indicated a significant main effect of process, $F(2,60) = 36.36$, and a significant interaction of process and phase, $F(4,120) = 3.04$.

The key point to be made about Figure 6 is that the writing tool failed to interact significantly with process and phase. Only two contrasts between tool conditions--reviewing during phase 1 and translating during phase 3--were marginally reliable ($p < .11$). Thus, the writers attended about the same amount of time to a given process regardless of writing tool, but the degree of momentary cognitive effort they expended on particular processes depended on the tool.

Additional data on restructuring of the review process were obtained from the final writing questionnaire, as shown in Figure 7. Students in the computer condition showed a significantly higher mean rating on the item concerning how their reviewing focused on local changes in mechanics such as spelling, grammar, and punctuation compared with those in the longhand condition, $F(1,30) = 4.17$.

Participants were asked to indicate which, if any, of their usual writing habits were omitted during the experiment. Two outcomes imply that writing on a word processor restructures planning. As shown in Figure 8, omission of doodling and drawing was significantly more frequent for writers in the computer condition than in the longhand condition, $X^2 = 4.57$. Moreover, as seen in Figure 9, omission of making notes was also most frequent in the computer condition, $X^2 = 10.49$.

Other Data

Several other measures were collected to rule out artifactual interpretations of our results. Reliable differences were not expected and none were obtained. The writing questionnaire showed that participants in the writing tool conditions did not differ significantly in self ratings of how often they use a computer for writing, how often they compose directly on the screen, how often they use the computer solely for revising handwritten drafts, how they rate the effectiveness of the computer in reducing the time needed to produce a paper, or in their typing skills. The mean percentile scores on the ACT English test were statistically equivalent as well. The final writing questionnaire showed that the participants in the two groups did not differ in their ratings of the quality of the essay they produced in the laboratory or their estimates of how efficiently they used the time allowed for writing. In short, the random assignment of participants successfully yielded equal groups on a number of potentially confounding variables.

Discussion

The present results show that word processing restructures writing processes, but fails to amplify writing performance. Most importantly, the pattern of allocating cognitive effort to writing processes interacted with the type of writing tool. Whereas effort was distributed about equally to planning, translating, and reviewing when writing longhand, a different pattern was seen on the word processor. Planning and reviewing consumed the most effort, and translating the least. Processing time, in contrast to cognitive effort, failed to show any interaction between writing tool and process.

This dissociation between cognitive effort and processing time is of general interest. Cognitive tools restructure thinking by altering the degree of momentary effort devoted to various processes, but not the amount of time spent attending to them. Earlier work of mine showed that domain specific knowledge restructured writing in a related fashion (Kellogg, 1987). Writers with a high degree of topic knowledge devoted substantially less cognitive effort to planning, translating, and reviewing than did those with low topic knowledge, but both groups allocated processing time in the same manner.

Relating these results to the well-known distinction between accessible controlled and automatic processing is complex and suggests the need for new theoretical distinctions. Presumably, an automatic process requires less effort and processing time than accessible controlled process (Shiffrin & Schneider, 1977). One cannot say, therefore, that domain specific knowledge automatizes writing processes, because only cognitive effort is affected. Similarly, one cannot conclude that cognitive tools cause planning and reviewing processes to be under greater control, because again only cognitive effort is affected. Processing time and cognitive effort must be considered independently in formulating how knowledge and tools restructures attentional allocation.

Two other outcomes show restructuring effects. First, the word processor led to a greater concern with local editing of mechanics during composition, based on retrospective reports after the experiment was completed. Bridwell-Bowles, Johnson, & Brehe (1987) reached a similar conclusion from their case studies of expert writers. Recall also that reviewing demanded more cognitive effort when done on the computer than by longhand in the present study.

Second, there was evidence that the nature of planning differed depending on the tool used. Making notes during composition is a planning technique that nearly all writers dropped from their usual writing method when composing on a word processor. Also, doodling and drawing was a habit of about a third of the writers that they had to drop when composing on the screen. From case studies of expert writers, Bridwell-Bowles et al. (1987) also concluded that word processing interferes with notetaking and graphical methods of planning.

The word processor examined here failed to amplify writing performance. Conceivably, a system might be designed that both restructures and amplifies cognition. For instance, the present results combined with others in the literature indicate that spelling aids, graphic-based idea processors for planning, and large screens for reading long sections of text might enhance writing fluency and quality (Kellogg, 1989; Haas & Hayes, 1986).

An important limitation of the present study is that the task was restricted to composing a short essay in a single session. Although this is an important task to investigate, given that such writing is common in business and school (Emig, 1971; Gould, 1980), other tasks should also be examined. If one could study in the laboratory the composition of a long document that undergoes numerous drafts over long periods of time, then evidence that the word processor improves writing performance might be obtained. The ease of revising on a word processor ought to have some positive impact. My own experience as well as anecdotal accounts by professional writers suggest this to be the case (Asimov, 1986; Zinsser, 1983).

However, previous efforts to measure benefits of word processing on long documents have proved disappointing. Surveys indicate that the productivity of a writer is surprisingly not correlated with use of a word processor (Hartley & Branthwaite, in press; Kellogg, 1986). Perhaps the ease of revising long documents is offset by certain costs. If making notes and diagrams is important in planning and the word processor inhibits these activities, then negative consequences are likely. Moreover, sentence generation may be interrupted more if writers adopt a perfect draft strategy in which they edit mechanics, word choice, and sentence construction as they compose on the screen. Lastly, attention must be given to formatting and other computer commands that are handled by a secretary working from a handwritten or dictated draft (Gould, 1981).

In conclusion, word processors may not make one a better or more efficient writer. But they do engage the writer's cognitive effort more in planning and reviewing and less in translating relative to composing in longhand. This restructuring of the allocation of cognitive effort is the major effect of at least one cognitive tool on thinking.

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Figure Captions

Figure 1. Mean rating of stylistic quality.

Figure 2. Mean rating of content quality.

Figure 3. Mean number of spelling errors.

Figure 4. Mean number of local, remote, and failed coherence links.

Figure 5. Mean cognitive effort scores for planning, translating, and reviewing (measured in msec of RT interference).

Figure 6. Mean percentage of time devoted to planning (P), translating (T), and reviewing (R) across each third of writing time.

Figure 7. Mean rating of focus on local changes in mechanics.

Figure 8. Percent of sample omitting doodling and drawing.

Figure 9. Percent of sample omitting making notes.

Figure 1

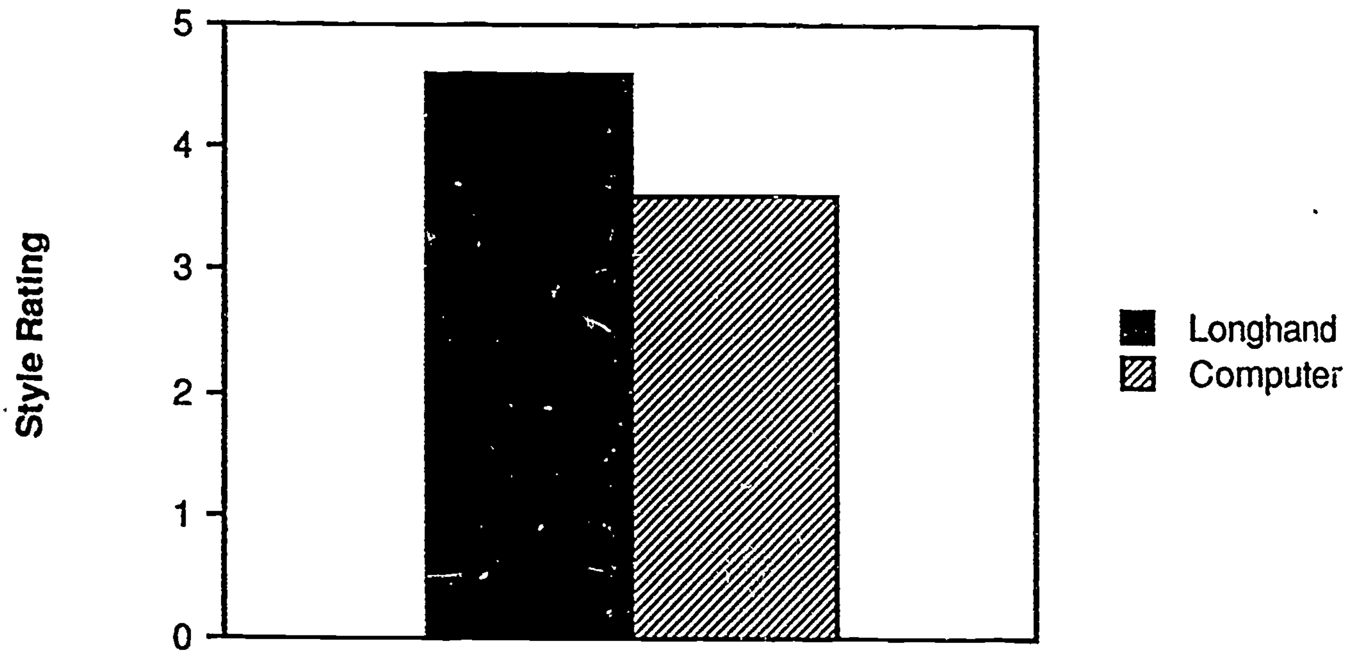


Figure 2

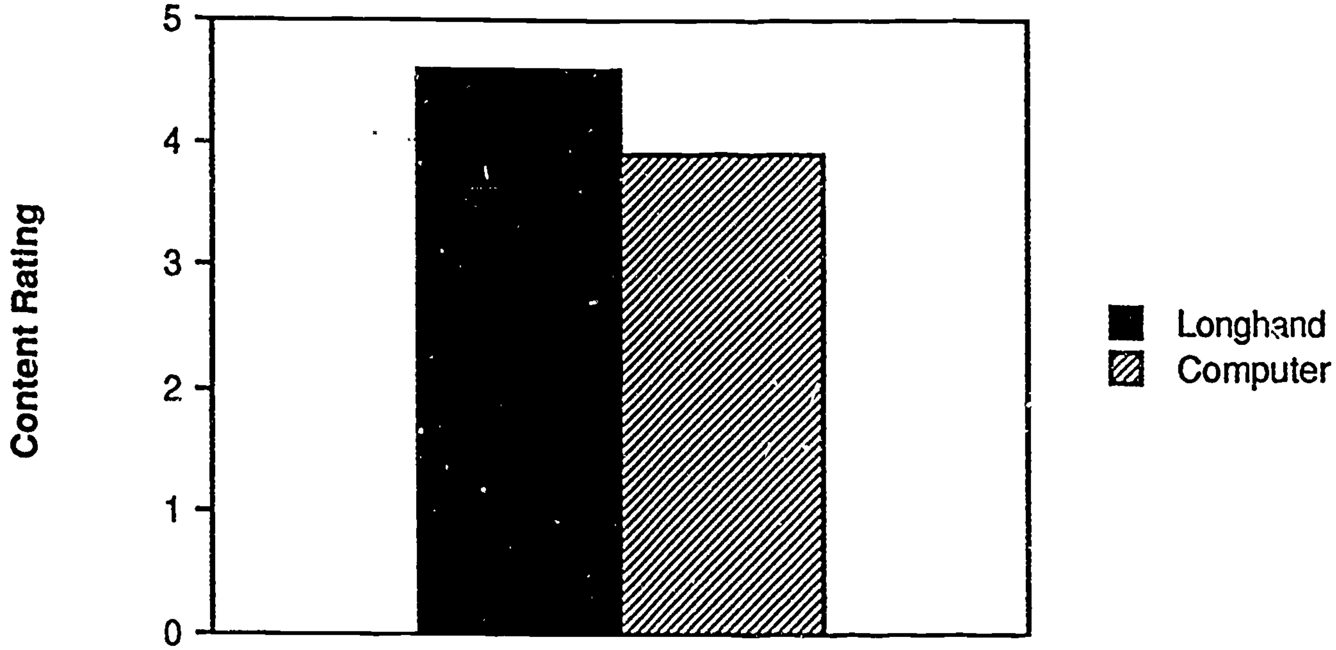


Figure 3

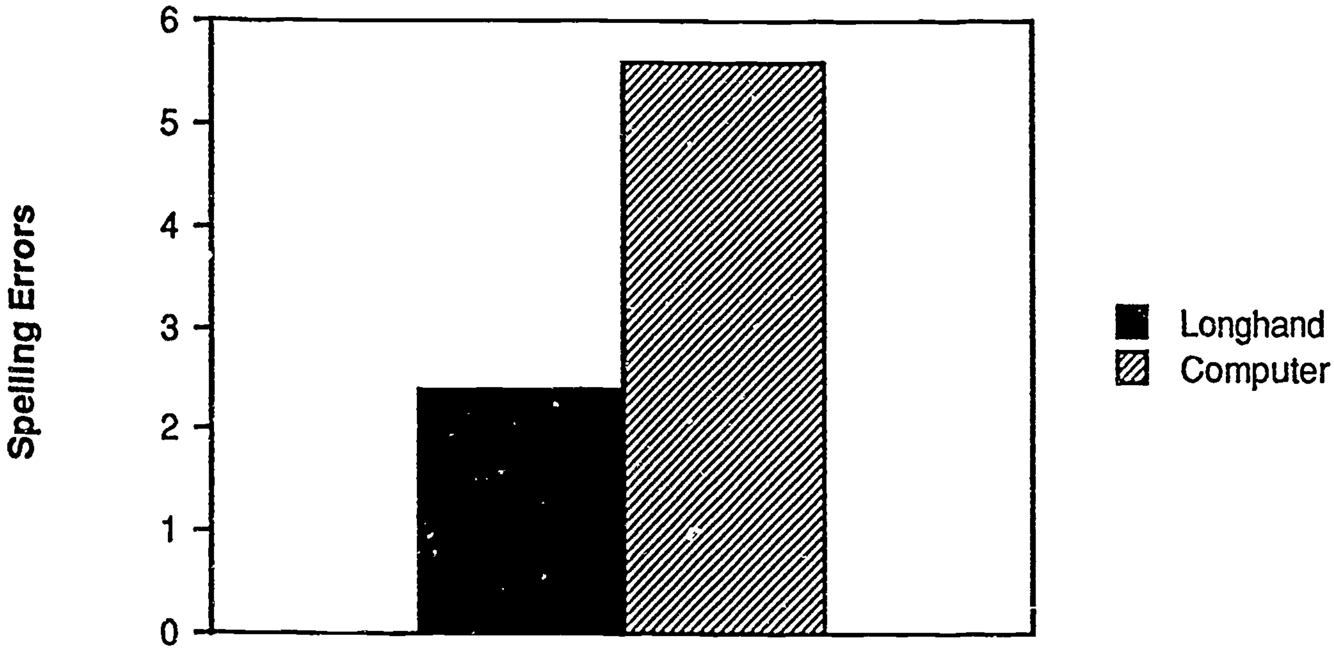


Figure 4

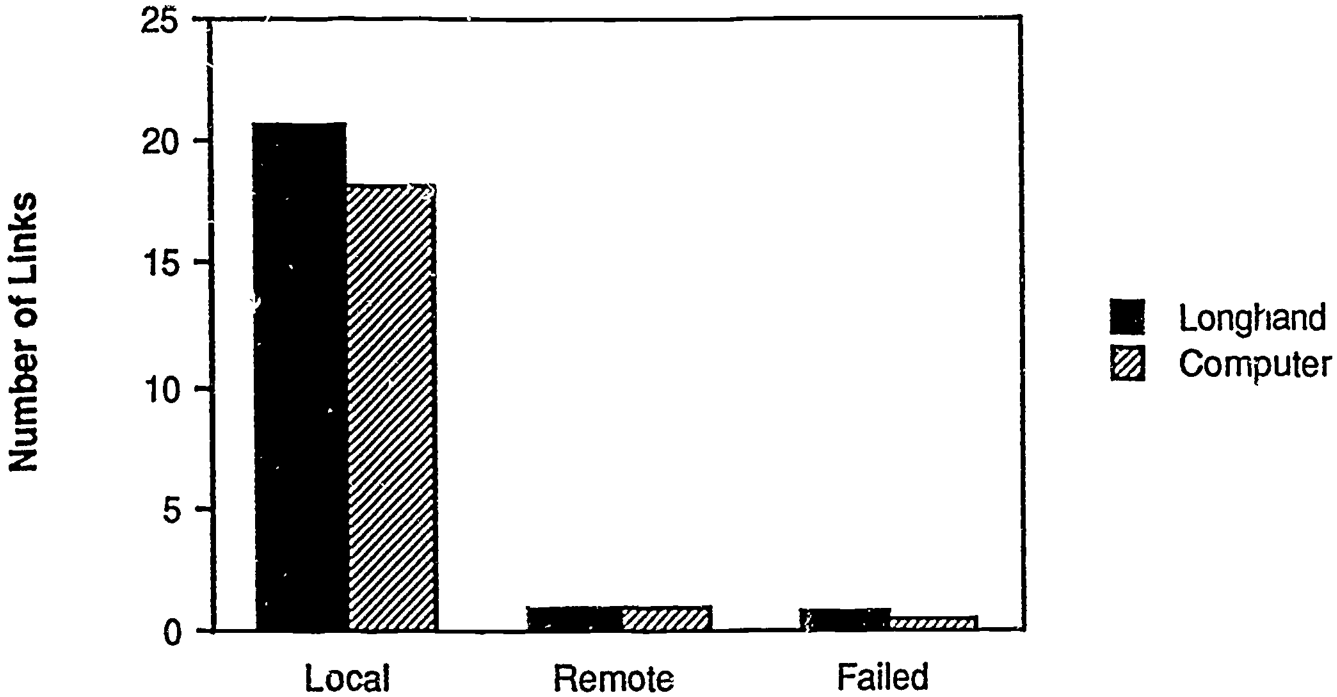
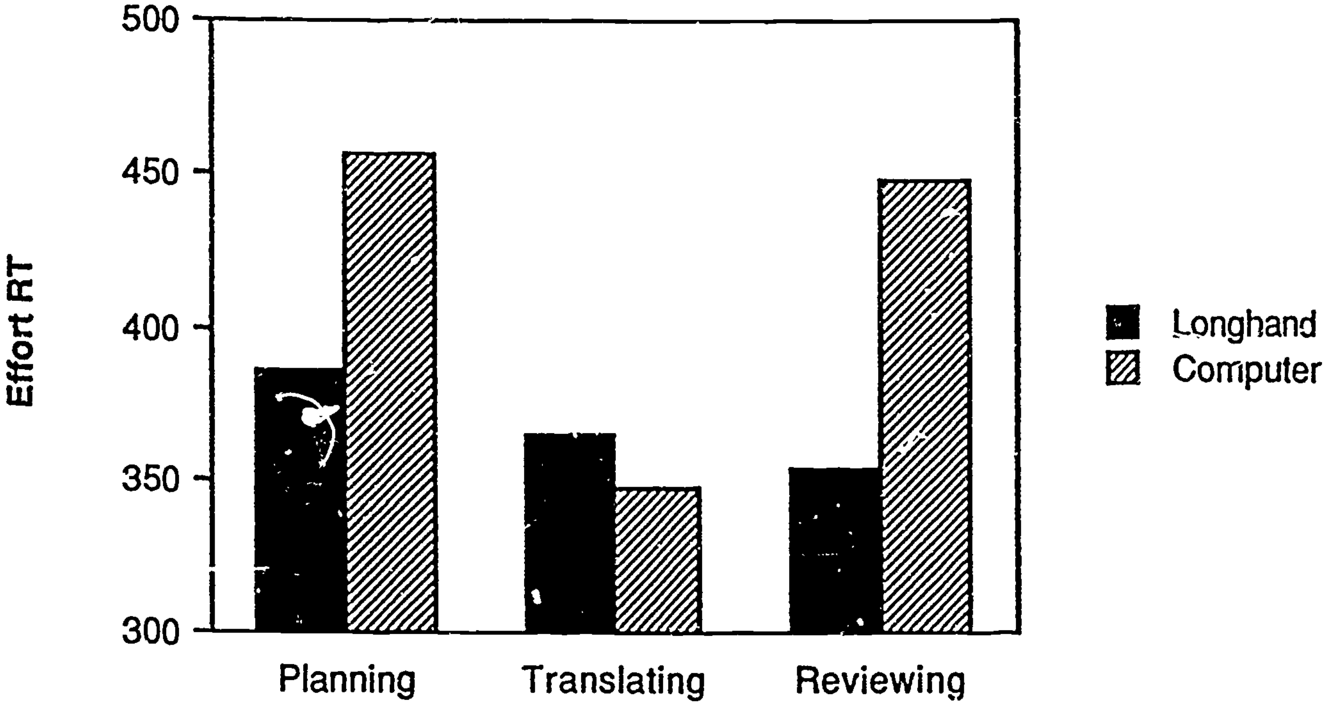

Number of Links
25
20
15
10
5
0
Local
Remote
Failed
Longhand
Computer

Figure 5



500
450
400
350
300
Effort RT
Planning
Translating
Reviewing
Longhand
Computer

Figure 6

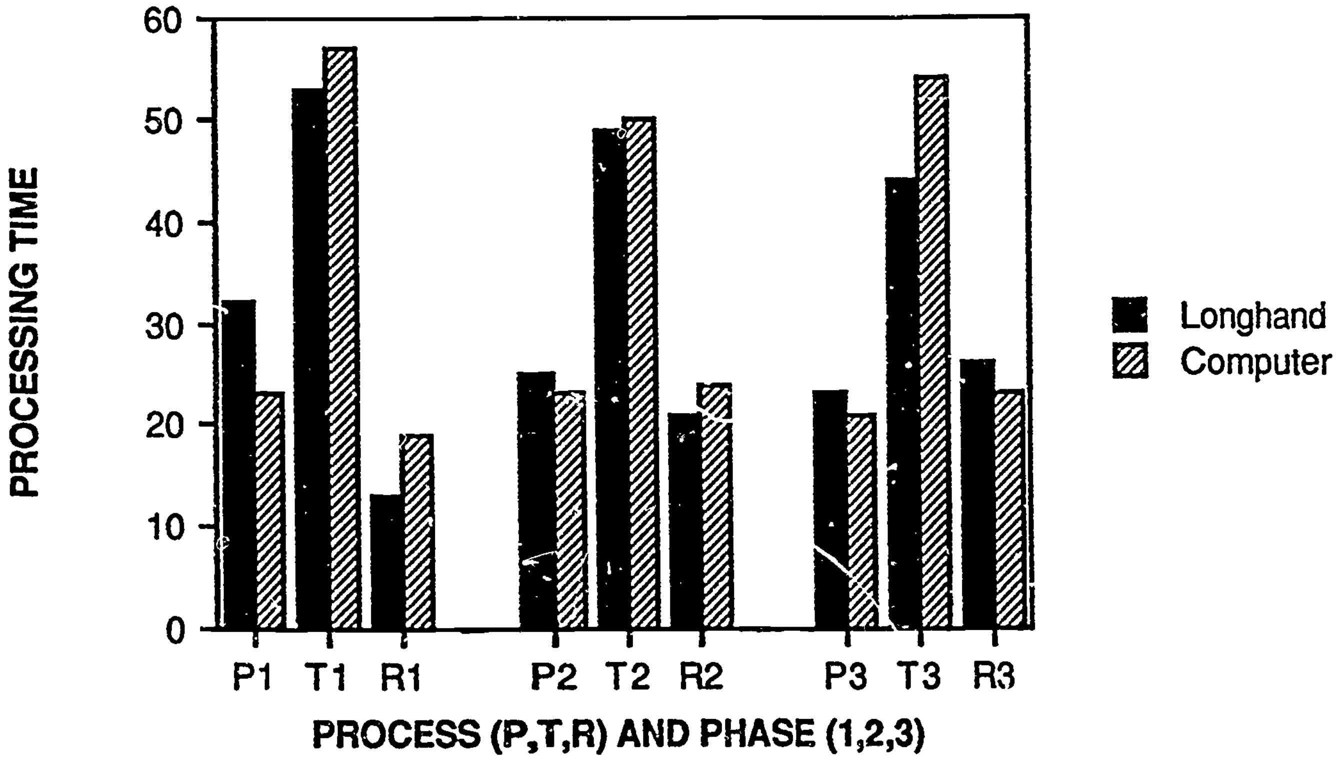

60
50
40
30
20
10
0
PROCESSING TIME
P1 T1 R1
P2 T2 R2
P3 T3 R3
PROCESS (P,T,R) AND PHASE (1,2,3)
Longhand
Computer

Figure 7

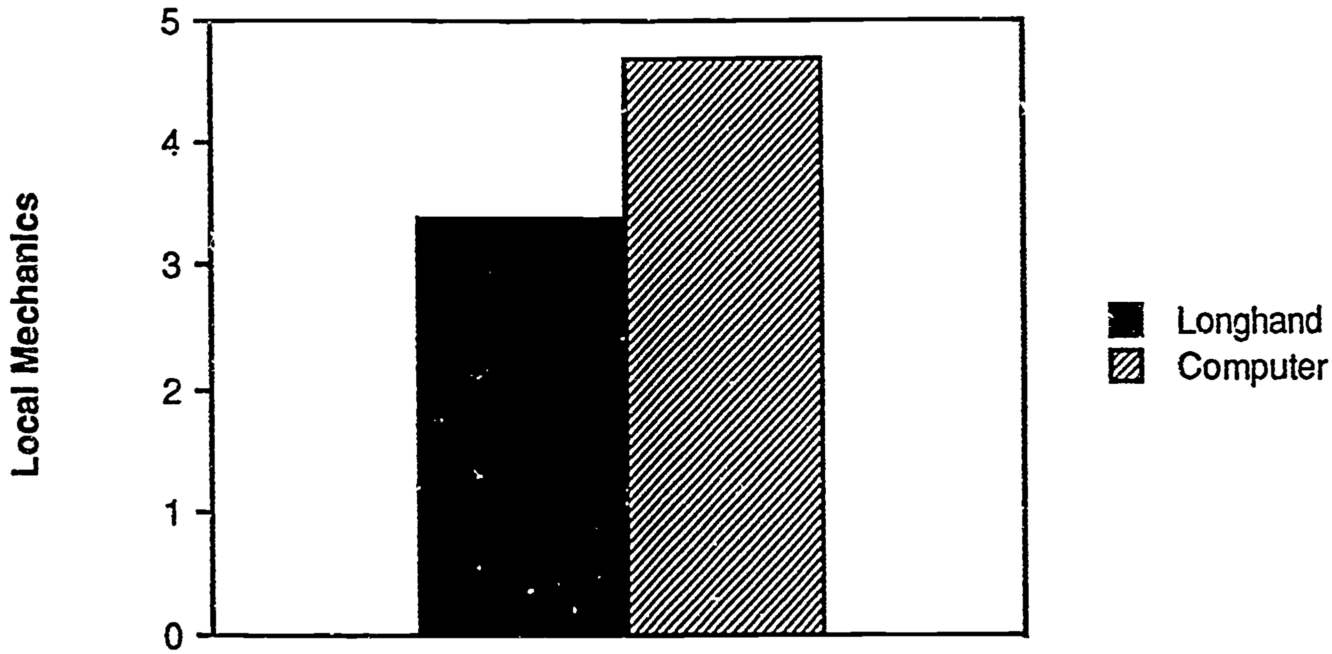


Figure 8

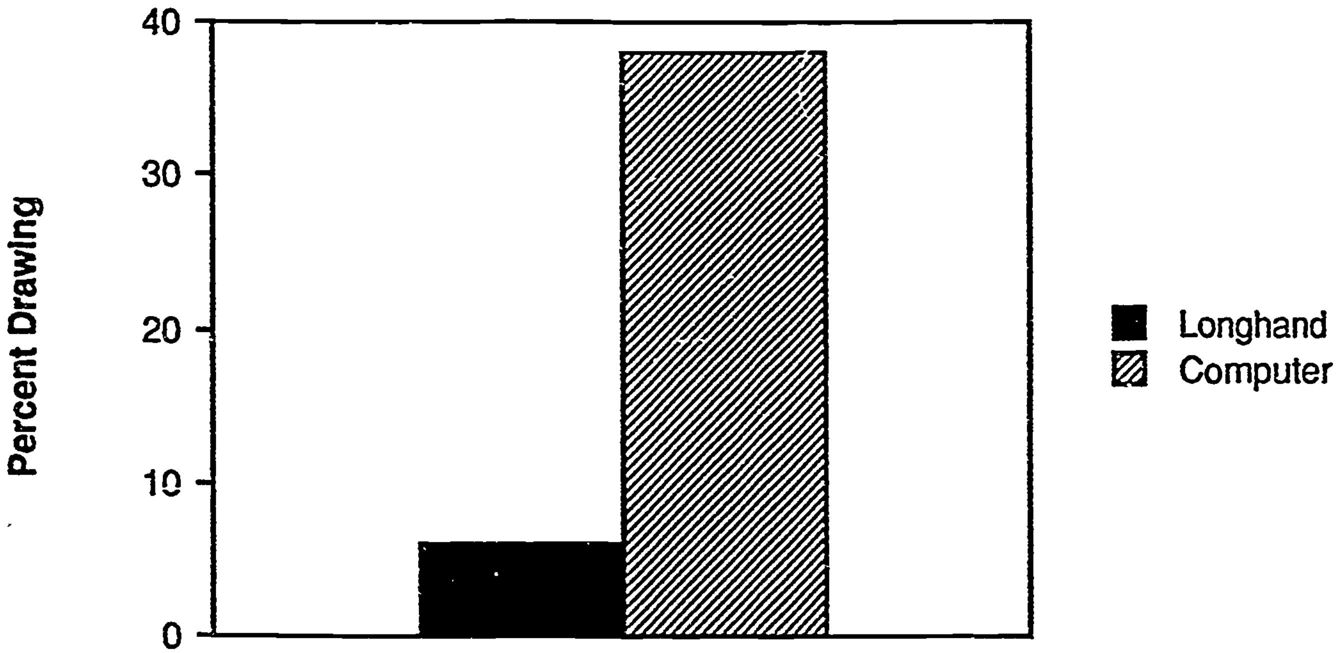


Figure 9