01 May 1987

Effects Of Topic Knowledge On The Allocation Of Processing Time And Cognitive Effort To Writing Processes

Ronald Thomas Kellogg
Missouri University of Science and Technology

Recommended Citation

Kellogg, R. T. (1987). Effects Of Topic Knowledge On The Allocation Of Processing Time And Cognitive Effort To Writing Processes. *Memory & Cognition, 15*(3), pp. 256-266. Springer; Psychonomic Society. The definitive version is available at https://doi.org/10.3758/BF03197724

Memory & Cognition
1987, 15(3), 256-266

Effects of topic knowledge on the allocation of processing time and cognitive effort to writing processes

RONALD T. KELLOGG
University of Missouri-Rolla, Rolla, Missouri

Conditions of low and high knowledge about the topic of a writing task were compared in terms of the time and cognitive effort allocated to writing processes. These processes were planning ideas, translating ideas into text, and reviewing ideas and text during document composition. Directed retrospection provided estimates of the time devoted to each process, and secondary task reaction times indexed the cognitive effort expended. Topic knowledge was manipulated by selecting subjects in Experiment 1 and by selecting topics in Experiment 2. The retrospection results indicated that both low- and high-knowledge writers intermixed planning, translating, and reviewing during all phases of composing. There was no evidence that low- and high-knowledge writers adopt different strategies for allocating processing time. About 50% of writing time was devoted to translating throughout composition. From early to later phases of composing, the percentage of time devoted to planning decreased and that devoted to reviewing increased. The secondary task results showed that the degree of cognitive effort devoted to planning, translating, and reviewing depended on the task. Also, the high-knowledge writers expended less effort overall than did the low-knowledge writers; there was no difference in allocation strategy across planning, translating, and reviewing.

Research on the writing process has increased markedly in recent years (Beach & Bridwell, 1984; de Beaugrande, 1980; Frederiksen & Dominic, 1981; Gregg & Steinberg, 1980; Nystrand, 1982). This interest is warranted given the importance of writing in work settings (Faigley & Miller, 1982; Odell & Goswami, 1984) and the concern raised by the ongoing National Assessment of Educational Progress that schools are not adequately preparing students in writing. Although research advances are being made, numerous basic questions remain, at best, only partially answered. One such question is how the knowledge of the writer affects the writing process. The importance of knowledge differences in other tasks, such as reading comprehension (Voss, Vesonder, & Spilich, 1980) and problem solving (Chi, Feltovich, & Glaser, 1981), suggests that this should be a key factor in writing.

Writers differ in what they know about their language, audience, and topic (Applebee, 1982). The present studies examined how knowledge of the topic being written about affects the amount of processing time and cognitive effort allocated to various writing processes. Although linguistic and audience knowledge also deserve exploration, they fall beyond the scope of this initial investigation. Processing time and cognitive effort were selected because, as will be discussed below, they concern two prominent features of writing based on current theory and empirical findings.

The author thanks the anonymous reviewers for the useful suggestions they provided on an earlier version of this manuscript. Requests for reprints should be addressed to Ronald T. Kellogg, Department of Psychology, University of Missouri—Rolla, Rolla, MO 65401.

Writing Phases and Processes

Before the specific issues under investigation are discussed, some key terms need to be defined. As a document develops from a writer's incipient ideas to a final draft, it moves through three broadly defined phases of composition: prewriting, preparing a first draft, and reworking subsequent drafts (Sommers, 1979). Each phase can involve four categories of processes: collecting, planning, translating, and reviewing (cf. Gould, 1980; Hayes & Flower, 1980; Nold, 1981). Collecting information involves searching bibliographic indices, reading source materials, and experiencing numerous activities, such as hearing a lecture or watching an event. Planning includes creating ideas, organizing ideas, and setting goals to achieve during composition, such as choosing an appropriate tone for a given audience. Translating ideas into text refers to lexical selection and sentence construction—actual language production. Finally, reviewing concerns reading the evolving text, evaluating the text or plans for text (both mental and written), and correcting errors.

The first prominent feature of writing is that collecting, planning, translating, and reviewing do not seem to occur in a simple linear sequence, with all collecting and planning taking place during prewriting, all translating during the first draft, and all reviewing on subsequent drafts. Evidence from case studies, using verbal protocols and interviews, suggests that collecting, planning, translating, and reviewing are recursive during all phases of composition, with any process leading to any other process (Bridwell, Johnson, & Brehe, 1986; Flower & Hayes, 1980b, 1984; Hayes & Flower, 1980; Kennedy, 1985;

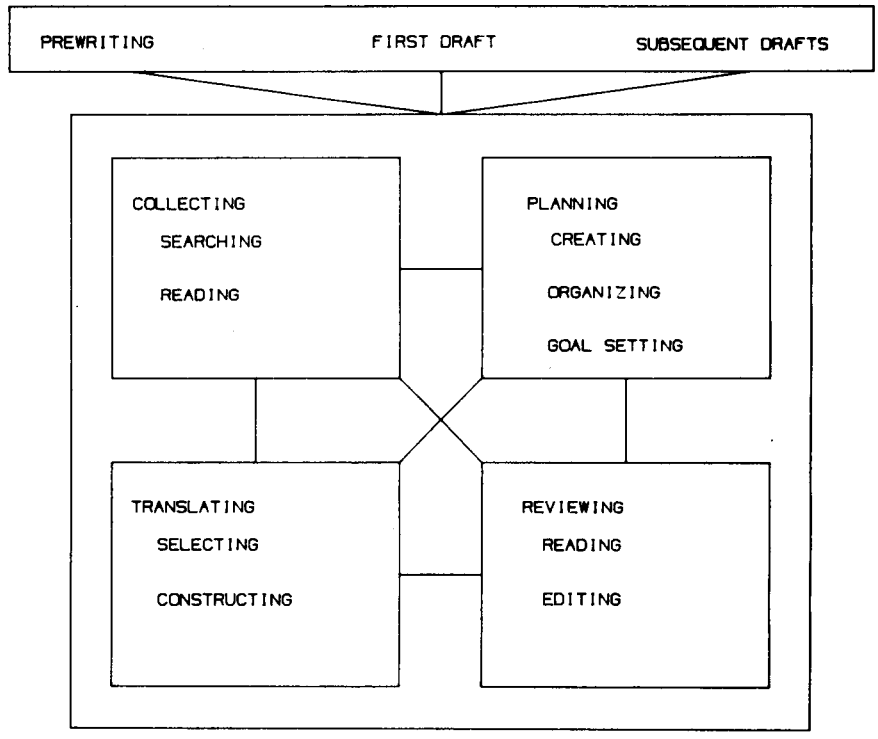

Figure 1. A model of product phases and recursive cognitive process in writing.

Nold, 1981). This complex view of writing is shown in Figure 1.

Allocation of Processing Time

Although it is valuable to recognize that composition may not proceed in a linear fashion, the model shown in Figure 1 obviously requires elaboration to be informative. For example, what percentages of processing time are devoted to collecting, planning, translating, and reviewing? How do these change as composing proceeds? Also, how do differences in topic knowledge affect the way in which processing time is allocated? Previous case studies have not been designed to answer such fundamental questions in a quantitative manner. Apparently the only experiments related to these questions have suggested that planning requires about two-thirds of total composition time for both handwriting and dictation methods of composing (Gould, 1978; 1980). Gould equated planning with pauses in generating (actual handwriting or dictating) that were not spent in reading or listening to already generated material.

The first purpose of this research was to answer the questions raised above regarding allocation of processing time. The experiments investigated the drafting phases of composition and not prewriting (see Figure 1). Also, collecting was not examined because the subjects were required to write from memory only, to rely solely on preexperimental knowledge.

It was predicted that planning, translating, and reviewing would be intermixed during the creation of first and subsequent drafts. The percentages of time given to these three processes, however, were not expected to be equal across early, middle, and late phases of drafting. The requirements of the task change as composition proceeds, and these changes should affect the allocation of processing time. Specifically, as the written product developed, the percentage of time spent planning was expected to decrease, whereas the percentages spent translating and reviewing were expected to increase. In addition, a highly knowledgeable writer may adopt a strategy of allocating processing time different from that adopted by a less knowledgeable writer (Flower & Hayes, 1980b; Nold, 1981). For instance, by knowing more about the writing topic, an individual may be able to spend less time planning and reviewing and more time translating than a less knowledgeable writer can. Selectively attending to a particular crucial process may be used by a highly knowledgeable writer during some phases of writing, say, early on in drafting, and not during other phases.

Allocation of Cognitive Effort

The second prominent feature of writing is the sheer effort of it all. The degree of momentary cognitive effort devoted to a process is as of much interest as the amount of time devoted to it. Cognitive effort is defined as the amount of available attentional capacity allocated to a specific process at a given instant (Tyler, Hertel, McCallum, & Ellis, 1979). The cognitive demands of writing can strain the limits of attentional capacity and working memory (Benton, Kraft, Glover, & Plake, 1984; Daiute, 1984; Glynn, Britton, Muth, & Dogan, 1982). Case studies of individuals suffering from writer's block (Boice,

1985; Rose, 1985), interviews with novelists (Cowley, 1957), and surveys of academic writers (Green & Wason, 1982) typically portray writing as a burdensome task.

Despite the recognition that writing is effortful, no previous study has directly measured the degree of cognitive effort invested by a writer and how effort is allocated to specific writing processes. The second purpose of the present research was to fill this gap. The basic questions guiding this exploration were as follows. Do planning, translating, and reviewing differ in their effort requirements? How does knowledge of the topic affect overall effort? And how does knowledge interact with writing processes in terms of effort requirements?

There is little theory from which to predict the relative effort requirements of planning, translating, and reviewing. Planning seems to be the most complicated and therefore probably the most effortful process (Flower & Hayes, 1984). Although planning is practiced extensively in the course of everyday activities (Miller, Galanter, & Pribram, 1960), such practice may not be similar enough to that which occurs in writing to be of great benefit in reducing effort requirements. For example, the subprocess of generating ideas challenges most writers. Graesser, Hopkinson, Lewis, and Bruflodt (1984) concluded that a central difficulty in writing is idea bankruptcy, an inability to generate informative, interesting, sophisticated, and relevant concepts. The literature on creativity reinforces the point that few individuals are fluent, flexible, and original in generating ideas (Guilford, 1967; Stein, 1974; Taylor & Barron, 1963). Moreover, once conceived, the ideas must be organized for clear communication, and a rhetorical plan must be developed for translating ideas into text (Flower & Hayes, 1980a, 1980b).

The translation process, in contrast, may well benefit from the extensive practice garnered from speaking. Granted, there are important differences in the communicative requirements for translating ideas into written versus spoken discourse (Green & Morgan, 1981; Groff, 1978). But there may be enough overlap between the two for translating to be relatively effortless. This in no way denies that writers sometimes do encounter problems in lexical selection or in constructing a sentence. But, overall, translating may be more automatic than planning and reviewing.

Reviewing seems to fall between planning and translating. Evaluating may not be extensively practiced, whereas reading undoubtedly is for most college students. Moreover, both reading and evaluating text and ideas seemingly would not be as difficult as planning ideas for text in the first place. One might take this argument further by claiming that translating—producing the text from ideas—should also be more effortful than reviewing. However, evaluating a document for clarity, organization, interest, and so forth involves highly complex decisions that are not well practiced (Nold, 1981). Consequently, reviewing probably demands more effort than translating.

The relation of prior knowledge and cognitive effort is well anchored in previous theory and findings. Britton and Tessor (1982) argued that retrieving and using knowledge requires cognitive effort. Experts with greater task-specific knowledge should therefore expend more cognitive effort than novices. Britton and Tessor offered support for this counterintuitive notion, what they called the prior knowledge hypothesis, by examining secondary task reaction times (RTs) and manipulating prior knowledge in tasks involving reading, chess move selection, and thinking about a specific topic. Conceivably, composing a document might show similar results to their linguistic and problem-solving tasks.

An alternative expectation is based on the concept of automaticity gradually developing with experience, referred to here as the workload hypothesis. The more an individual knows about a topic, the less effortful it might be to retrieve and use the relevant knowledge in preparing a written document. One potential advantage of knowledgeable writers in handling the severe workload of composing is having the option of drawing on relatively routinized, automatic procedures (Flower & Hayes, 1980b; Nold, 1981).

A finding consistent with the workload hypothesis is that college upperclassmen report carrying out more cognitive operations during pauses in writing, while requiring less pause time, than college freshmen (Schumacher, Klare, Cronin, & Moses, 1984). These researchers suggested that the upperclassmen had practiced writing more and that their greater level of automaticity enabled them to do more in less time than the freshmen. It is difficult to say whether the advantage came from a greater degree of skill in using language, thinking about the topic, or sensing the needs of the audience.

The college students in the present experiments presumably shared the same level of linguistic skill and audience awareness but differed across conditions in their knowledge of writing topic. Conceivably, the better one knows the writing topic, the less effort might be needed to plan, translate, and review text. The workload hypothesis contrasts with the prior knowledge hypothesis in predicting less expenditure of effort for high-knowledge individuals.

Finally, it seems reasonable to expect an interaction of topic knowledge and specific processes regarding cognitive effort. The chief benefit, according to the workload hypothesis, or the chief cost, according to the prior knowledge hypothesis, should fall on planning. Topic knowledge is directly tied to generating and organizing ideas. Therefore, planning should be more influenced by the effects of topic knowledge than would either translating the ideas into text or reviewing the ideas and text. Note that if knowledge of the language rather than the topic were manipulated, then translating would probably be most affected.

Experimental Rationale

The present experiments measured the amount of time spent on planning, translating, and reviewing, using a directed retrospection technique (Ericsson & Simon,

1980), and the degree of cognitive effort allocated to each process, using the secondary-task-RT technique (Kahneman, 1973; Kerr, 1973). College students wrote persuasive documents in a single sitting. On a variable-interval schedule, they heard an auditory signal while writing.[1] This was a signal for the subjects to say "Stop" as quickly as possible, and their RTs were recorded. After each signal, the subjects pressed one of four buttons to indicate whether their thoughts at the time of the signal reflected planning, translating, or reviewing or were unrelated to these. The subjects were trained to identify their thoughts in terms of these four categories. The cognitive effort associated with each specific process was defined in terms of the increase over baseline RT, which was assessed when the subjects were not writing.

The amount of prior knowledge regarding the writing topic was manipulated. In Experiment 1, this variable was manipulated by selecting subjects who knew more or less about the topic. In Experiment 2, the topic itself was selected to ensure differences in how much the subjects knew.

EXPERIMENT 1

In Experiment 1, scores on a test were used to assign the subjects to low- and high-knowledge conditions, following the procedure used by Voss et al. (1980) in their work on topic knowledge in discourse comprehension and memory. Directed retrospection provided estimates of the proportion of writing time devoted to planning, translating, and reviewing. Secondary-task RTs assessed the degree of effort associated with each process.

Measurements of efficiency and quality of writing were also taken. The amount of time spent writing and the number of words composed per minute (WPM) indexed the efficiency of writing.[2] Product quality was evaluated by having two readers judge the documents on several scales of document quality. Although obtaining reliable and valid judgments of text quality is a difficult enterprise (Charney, 1984; Freedman & Calfee, 1983), measurements of both the efficiency and quality of writing were needed to interpret the presence or absence of differences between low- and high-knowledge subjects in the amount of effort devoted to writing processes.

For instance, the prediction of the workload hypothesis would be strongest when both low- and high-knowledge writers were equally efficient in composing documents of equal quality; in this case, the high-knowledge subjects should clearly expend less effort if this hypothesis has merit. But suppose the high-knowledge subjects composed a superior-quality document more efficiently than those with low knowledge; in this case, the high-knowledge subjects might well expend the same degree of effort as low-knowledge subjects without necessarily damaging the workload hypothesis. Despite high-knowledge individuals' requiring less effort to yield equivalent efficiency and quality, they may elect to give more effort to achieve superior writing performance. Although Britton and Tessor (1982) did not monitor process efficiency and product quality, the quality of performance on one of their tasks, reading, had been checked in previous research in terms of passage recall (Britton, Holdredge, Curry, & Westbrook, 1979).

Method

Subjects and judges. Thirty college students were divided evenly into the low- and high-knowledge conditions on the basis of a test about the United Nations. The test included 25 multiple-choice items regarding the history, organization, and purpose of the United Nations (median score = 11). They received credit in their general psychology course for participating. The subjects were tested individually.

Two paid judges rated the documents for quality. Both judges had scored in the 87th percentile or better on the ACT verbal subtest; one was an English composition major, and the other was a psychology major who had taken composition courses and wrote poetry and short stories as a hobby. They judged language usage, organizational coherency, idea development, effectiveness, and mechanics; these dimensions were developed by Atlas (1979) for a standardized test of writing skills of college freshmen. They read a standardized set of instructions that defined each dimension, encouraged the rater to use the full 7-point scale, and required the rater to read quickly through all documents before assigning values to any and to take as much time as necessary to judge all the documents as accurately and as fairly as possible. The judges worked independently and were blind to the experimental condition associated with each document.

Writing task. The data of Experiment 1 were collected in the wake of the Korean airliner incident. Following the downing of the airplane by the Soviet Union and the proposal by the United States to ban Soviet flights into airports of New York, the Soviets suggested that the United Nations be moved to "more neutral" territory. The subject's task was to write a persuasive essay on why the United Nations should remain in New York City.

Procedure. First, the experimenter trained the subjects in the method of directed introspection. Second, the secondary RT task was introduced. The subjects were informed that occasionally while writing they would hear a beep (generated by an Apple II computer). This was a signal for the subjects to say "Stop" as quickly as possible into a microphone positioned in front of them. The RT was recorded in milliseconds. After having said "Stop," the subjects retrospected about their thoughts at the moment the signal had occurred. They pressed one of four buttons, positioned in front of the hand that they were not writing with, to indicate whether their thoughts at that moment had best reflected planning, translating, reviewing, or some other process unrelated to these. The subjects were instructed to attend primarily to the writing task; they were asked to carry out the signal-detection and retrospection tasks without disrupting their concentration on writing. In addition to the Apple II, a Gerbrands voice-activated relay and a Digitry cognitive testing station were used in recording the subject's RT and retrospective responses.

After the RT instructions were delivered, each subject responded to three to five signals as practice and to allow adjustment of the voice-activated relay for the individual's speaking loudness. Next, a series of 30 single-task baseline RTs were collected. The first five trials were treated as warm-up trials and were omitted from calculations of baseline RT. The signal occurred on a variable-interval schedule, with a mean interval of once every 10 sec and a range of 5 to 15 sec. During the writing task, the signals occurred on a variable-interval schedule of once every 30 sec, on average; the range of these dual-task trials was 15 to 45 sec. The purpose of the variable-interval schedules was to preclude the possibility of anticipating the occurrence of a signal. Different baseline and dual-task schedules were used to hasten the collection of baseline

data (the entire experiment required 60 to 90 min, depending on the time spent writing) and to ensure an unintrusive signal while the subject was writing.

The subjects were presented with the writing task immediately after collection of baseline trials and were asked to read the instructions carefully. The experimenter asked if they had questions about the writing assignment. The subjects then were asked to think about their writing task for 5 min before they began to compose. During this prewriting time, they were to make mental notes and mental outlines of what they wanted to write. They were not given the writing pen and paper until this 5-min planning period had elapsed.

They were told to take as much time as they needed to explain their position well and to change the text as often as they liked by adding, deleting, and rearranging words. They wrote in pen and were not allowed to erase anything. Total writing time, then, reflected both first- and subsequent-draft phases of composing. Finally, they were reminded to respond to the signals as fast as possible, to retrospect by pushing the appropriate button, and to resume writing as soon as they had finished retrospecting. They were reminded to concentrate fully on their writing and to avoid trying to anticipate when a signal would occur.

The experimenter used a digital stopwatch to measure the amount of time spent writing the document for all conditions. After having finished the writing task, all subjects were debriefed regarding the purpose of the experiment.

Results and Discussion

Retrospection. To examine strategy differences in the allocation of processing time, total writing time was divided into thirds, and then the percentage of times that the subject had reported planning, translating, and reviewing was calculated for each of the three phases. The percentages do not add to 100 because of the few times that the subjects reported the unrelated category. These data are presented in Figure 2 for the low- and high-knowledge conditions. An analysis of variance (ANOVA) in which process and phase were treated as within-subjects variables was performed on the percentage-of-writing-time data.

From the retrospective reports, it appears that, across all phases, the writers in both knowledge conditions spent slightly more than 50% of their time translating. Again in both conditions, the amount of time spent planning decreased across phases, whereas reviewing increased. The main effect of process [$F(2,56) = 42.20$, $MSe = 6.14$, $p < .001$] and the interaction of process and phase [$F(4,112) = 10.81$, $MSe = 2.92$, $p < .001$] were the only significant sources of variance. The critical two- and three-way interactions involving process and knowledge conditions yielded Fs < 1.0. Thus, there was no indication that high-knowledge subjects adopted a strategy for allocating processing time different from the strategy adopted by the low-knowledge subjects.

Cognitive effort. Across all subjects and auditory signals, 2.5% of the RTs were dropped due to failures to obtain accurate readings (the subject spoke too softly for the sensitivity setting of the relay). Median RTs were computed for each subject for baseline, planning, translating, and reviewing and were entered into an ANOVA. Too few observations for the unrelated category precluded an analysis of these RTs.

The mean RTs (in milliseconds) for the low- and high-knowledge conditions, respectively, are given in parentheses for each type as follows: baseline (329 vs. 363), planning (759 vs. 664), translating (703 vs. 623), and

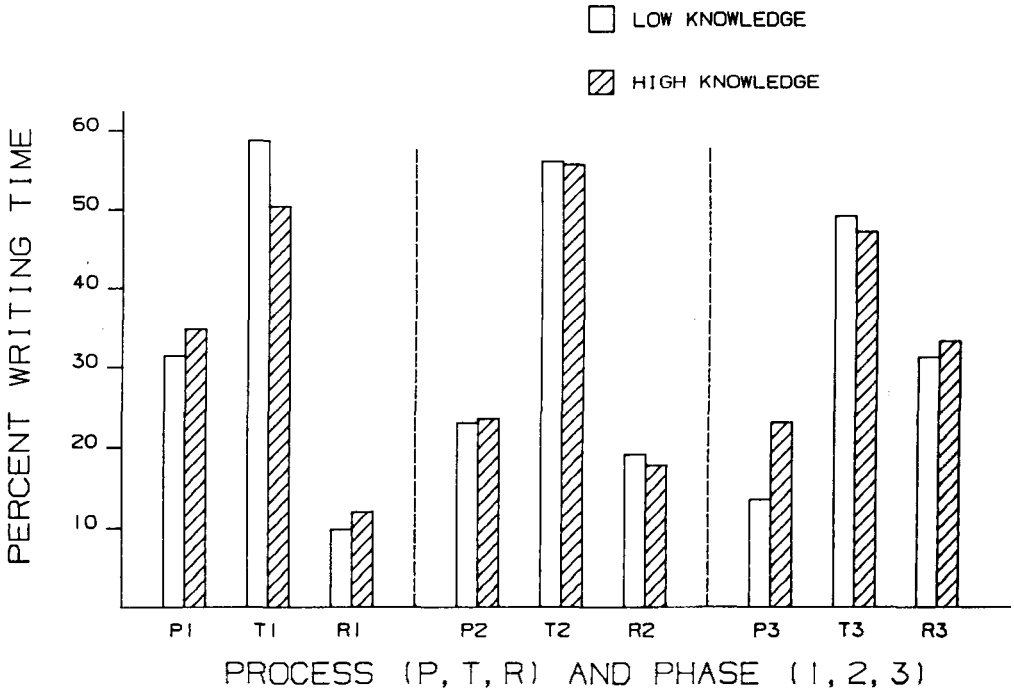

Figure 2. Mean percentage of time devoted to planning (P), translating (T), and reviewing (R) across each third of writing time in Experiment 1.

reviewing (745 vs. 665). There were a significant main effect of RT type [$F(3,84) = 95.56$, $p < .001$] and an interaction of type and knowledge condition [$F(3,84) = 2.72$, $p < .05$] ($MSe = 9.94$ for both effects). Baseline RTs were markedly lower than for the other types, and there were sizable differences between knowledge conditions for all types except baseline RTs.

Interference scores were calculated for each subject by subtracting the median baseline RT from the medians for planning, translating, and reviewing. The greater the interference in secondary task RT, the more effort the subject allocated to a given process. The condition means (in milliseconds) for these interference scores are shown in Figure 3.

An ANOVA revealed two significant sources of variance. First, a main effect of knowledge condition [$F(1,28) = 4.37$, $MSe = 73.10$, $p < .05$] was obtained in the direction predicted by the workload hypothesis. Second, a main effect of process [$F(2,56) = 3.64$, $MSe = 5.72$, $p < .05$] was found. Tukey's a test indicated that, as predicted, translating consumed less effort than did planning or reviewing. Contrary to expectations, however, reviewing showed as much effort expenditure as did planning. These relationships held for both low- and high-knowledge conditions. Hence, there was no evidence that high-knowledge writers followed a different strategy for allocating cognitive effort.

Writing performance. No significant differences were observed between the knowledge conditions on several measures of writing performance. With respect to efficiency measures, low- and high-knowledge subjects (respective means are given in parentheses) wrote about the same number of minutes (25.8 vs. 24.4) at the same WPM rate (12.37 vs. 12.08). The quality judgments made by the two readers were averaged for each document.[3] The mean scores for low- and high-knowlege subjects were essentially equivalent in terms of language usage (4.00 vs. 4.10), organizational coherence (3.76 vs. 3.76), idea development (3.60 vs. 3.43), effectiveness (3.17 vs. 3.06), and mechanics (3.97 vs. 4.23).

As in indirect measure of quality, the documents were also scored in terms of the number of words inserted and number deleted in the final version. It was anticipated that the better documents may have undergone more modifications. These data were highly variable. No significant difference was observed between low- and high-knowledge conditions in terms of the words deleted (9.33 vs. 16.60). A marginally significant difference was observed [$F(1,28) = 2.88$, $MSe = 91.53$, $p < .10$] in the number of words added (9.33 vs. 3.40). But the trend favored the low-knowledge group.

To summarize, the results of Experiment 1 suggest important constraints on the writing model portrayed in Figure 1. Although writers did not first do all of their planning, then translating, and then reviewing in linear fashion, they clearly decreased the amount of planning and increased the amount of reviewing as composing proceeded. Only the amount of translating remained constant across the three phases of drafting, with roughly 50% of processing time allocated in each phase. Knowledge of the topic had no impact on the allocation of processing time. Similarly, writers of both levels of topic knowledge

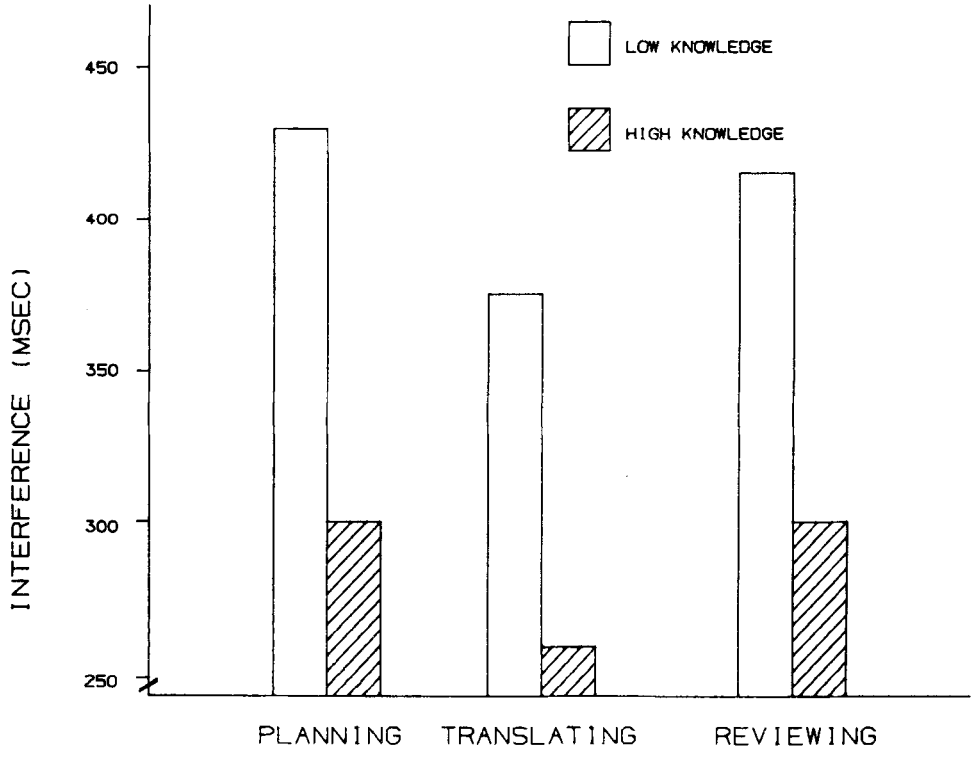

Figure 3. Mean scores of secondary task RT interference in Experiment 1.

followed the same strategy in allocating cognitive effort to specific processes. However, taken overall, high-knowledge writers allocated substantially less cognitive effort to all writing processes than did low-knowledge writers, as predicted by the workload hypothesis. In support of the hypothesis that translating in writing benefits from the extensive practice gained through speaking, translating showed a lower level of effort expenditure than did both planning and reviewing. Interestingly, reviewing was just as effortful as planning, reinforcing the point that evaluating ideas and text can involve demanding high-level decisions that have not received extensive practice.

EXPERIMENT 2

The generality of the findings of Experiment 1 was assessed here. There is a potential problem with manipulating knowledge conditions by using subject characteristics (test scores). It may yield nonrandom assignment to conditions. Conceivably, some characteristic other than topic knowledge per se, such as intelligence, may correlate with test scores and be the true effective variable governing degree of effort expended in writing. The generality of the findings favoring the workload hypothesis would be enhanced if knowledge of the topic were manipulated in some other way, using random assignment to conditions.

In Experiment 2, knowledge was manipulated by varying the topic itself. Half the subjects, randomly determined, wrote about a topic that they, as college students, presumably had thought about to a considerable degree in the past, and the other half wrote about a fictitious topic that they probably never had considered. By selecting new topics in this experiment, it was also possible to assess the generality of all other results of Experiment 1. Finally, the sample size was doubled to ensure adequate statistical power for detecting interactions between knowledge conditions and writing processes.

Method

With the exception of the writing task and the method used to manipulate low- and high-knowledge conditions (n = 30), Experiment 2 was the same as Experiment 1. No quiz regarding topic knowledge was administered. Instead a topic familiar to most college students, university tuition, was selected for the high-knowledge condition, and an unfamiliar role-playing task, a fictitious antigreed club, was used for the low-knowledge condition. Both topics were adopted from writing-sample problems used on the Law School Admissions Test (Bobrow, 1979).

The instructions given to the subjects in the low-knowledge condition were:

> Imagine that you are a successful professional. An "Anti-Greed" Club has been formed in your neighborhood. All the members of this club are professionals like you (attorneys, physicians, business executives, etc.) who earn over $50,000 per year. Each member pledges to give annual income over $50,000 to poor families in the community. The recipients and amount each receives are decided by chance—that is, by a drawing. Several members of your social club are considering joining the "Anti-Greed" Club and have asked your help in making an objective, rational decision. Write a paper giving the pros and cons of such a move as you see it. Be careful to give fair treatment to both sides of the issue, regardless of how you feel about it personally.

The task description for the high-knowledge condition provided the subjects was:

> As state-supported universities begin to feel the effects of inflation, many are asking students who are state residents to pay tuition, just as out of state students do, in addition to the incidental fees they ordinarily pay. These resident students for whom a college education was relatively inexpensive are now complaining that even minimal tuition is an unfair burden. Write an article for the college newspaper in which you develop an argument for or against tuition for all state university students. Be careful to anticipate and defend against possible counterarguments.

Results and Discussion

Retrospection. Once again, total writing time was divided into thirds, and the percentage of times that the subject reported planning, translating, and reviewing was calculated. The mean percentages are shown in Figure 4; they do not add to 100 because of the few times that the other category was reported.

The data are similar to those observed in Experiment 1. About 50% of writing time was devoted to translating in both knowledge conditions across all phases. A decrease in planning time and an increase in reviewing time were observed across phases for both knowledge conditions. The subjects in the high-knowledge conditions allocated processing time to planning, translating, and reviewing roughly the same as did those in the low-knowledge conditions. There was a nonsignificant trend for the low-knowledge subjects to spend more time reviewing in Phase 2 and more time planning in Phase 3 than the high-knowledge subjects. An ANOVA supported these descriptive conclusions by yielding a main effect of process [$F(2,116) = 89.48$, $MSe = 5.40$, $p < .001$] and an interaction of process and phase [$F(4,232) = 25.89$, $p < .001$]. The three-way interaction of process, phase, and knowledge condition was marginally significant [$F(4,232) = 2.14$, $p < .08$] ($MSe = 2.18$ for both interactions).

Cognitive effort. Across all subjects and auditory signals, 4.2% of the RTs were dropped due to failure to obtain accurate readings (the subject spoke too softly for the sensitivity setting of the relay). The data were analyzed as in Experiment 1, and the mean RTs (in milliseconds) for the low- and high-knowledge conditions, respectively, are given in parentheses for each type as follows: baseline (280 vs. 291), planning (604 vs. 557), translating (602 vs. 546), and reviewing (597 vs. 546). An ANOVA produced a significant main effect of process [$F(3,174) = 208.86$, $p < .001$] and a marginally significant interaction of process and knowledge condition [$F(3,174) = 2.50$, $p < .06$] ($MSe = 6.03$ for both effects).

To interpret these RTs in terms of expended effort, interference scores were calculated as in Experiment 1. The mean interference scores (in milliseconds) are shown in

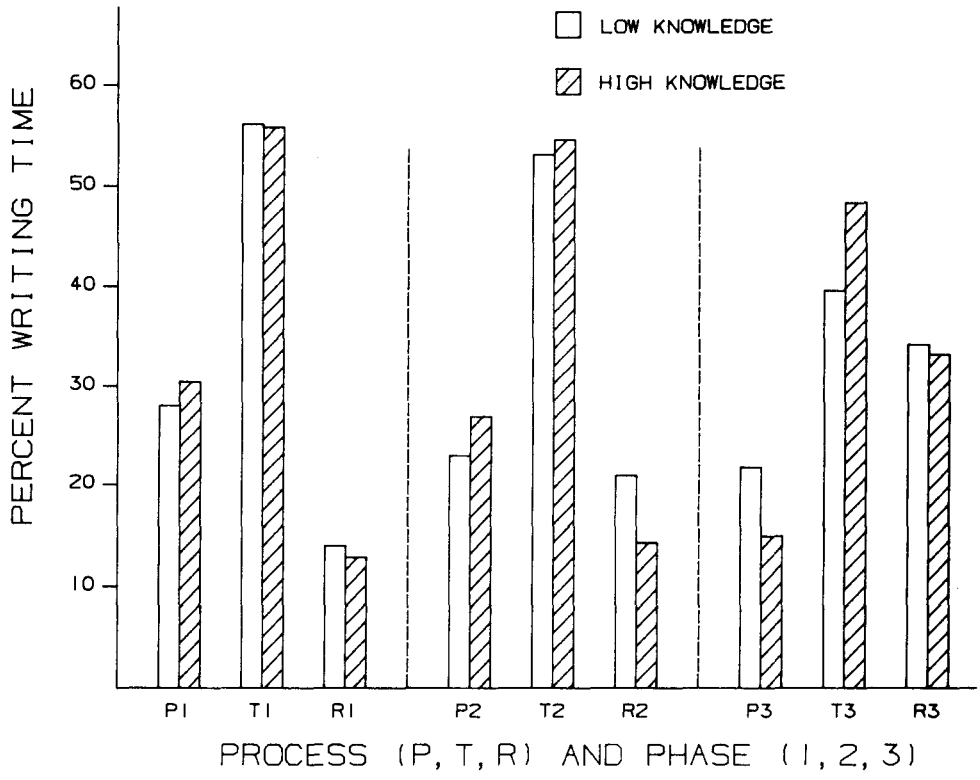

Figure 4. Mean percentage of time devoted to planning (P), translating (T), and reviewing (R) across each third of writing time in Experiment 2.

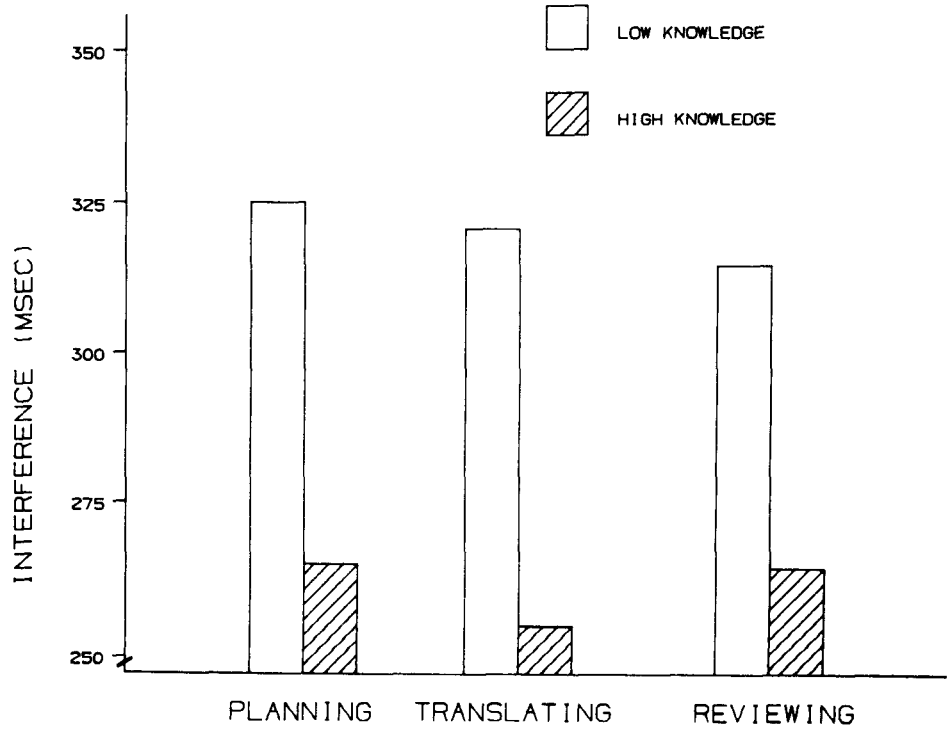

Figure 5. Mean scores of secondary task RT interference in Experiment 2.

Figure 5. An ANOVA revealed only a main effect of knowledge condition [$F(1,58) = 5.17$, $MSe = 31.61$, $p < .05$]. As in Experiment 1, the subjects in the high-knowledge condition expended markedly less effort than did those in the low-knowledge condition. But unlike in Experiment 1, no significant differences were observed among planning, translating, and reviewing.

Writing performance. As in Experiment 1, no significant differences were obtained between knowledge conditions on measures of efficiency and quality of writing. The low- and high-knowledge subjects (respective means on the 7-point scales are given in parentheses) wrote about the same number of minutes (36.17 vs. 31.23) at the same WPM rate (11.06 vs. 10.49). The quality judgments made by the two readers were averaged for each document.[4] The mean scores for low- and high-knowledge conditions were roughly the same in terms of language usage (4.13 vs. 3.98), organizational coherency (3.83 vs. 3.65), idea development (3.95 vs. 3.52), effectiveness (3.58 vs. 3.37), and mechanics (3.88 vs. 3.92). Finally, low- and high-knowledge subjects failed to differ significantly either on the number of words added (9.87 vs. 8.70) or on the number of words deleted (20.43 vs. 19.77).

GENERAL DISCUSSION

Taken together, the experiments suggest the following conclusions. Both writers with low and high topic knowledge blend planning, translating, and reviewing during all phases of composition, as implied by the model shown in Figure 1. However, the percentage of time spent planning decreases and that devoted to reviewing clearly increases from early to late phases of composing. About 50% of writing time is given to translating during all phases. The degree of cognitive effort devoted to planning, translating, and reviewing seems to depend on the specific writing task. The pattern of effort expenditure across planning, translating, and reviewing is the same for writers with low and high knowledge of the topic. However, summing across these processes, high-knowledge writers devote markedly less effort overall than do low-knowledge writers. These conclusions represent important constraints for the general model portrayed in Figure 1.

It is clearly incorrect to think of writing as a linear progression from planning, to translating, to reviewing. Yet, it is also wrong to view the writer as spending equal time on these processes during all phases of composing. The data shown in Figures 2 and 4 portray an allocation of processing time that is intermediate between these extremes. It would be interesting to know the probabilities of shifting from one process to another as well as the percentages of time allocated. These transition probabilities were not computed because the random schedule for retrospective probes employed here would not yield meaningful results. To compute transition probabilities, one would need to probe the subject regularly and frequently, perhaps every few seconds. The present probe procedure, in contrast, was designed to be as unintrusive and unpredictable as possible.[5]

About 50% of writing time was given to translating across all phases of composing. The other two processes were attended to at most only about 30% of the time, with the peak for planning occurring in the early phase and the peak for reviewing coming in the late phase of composing. These results seem to conflict with Gould's (1978, 1980) findings that planning requires about two-thirds of writing time. The inconsistency may be due to differences in methodology.

The estimates in the present experiments were based on retrospective reports, whereas Gould's (1978, 1980) measurements were derived from behavioral observations of pauses. He defined planning time as any pause in handwriting that was not spent in reading already produced text. In the experiments reported here, rather than trying to infer from pauses, we used the subject's report to estimate planning, translating, and reviewing time.[6] During a pause, a writer might be planning ideas, but he or she might also be mentally translating ideas into text or evaluating the adequacy of text after having read it. Gould's estimate of planning time could reflect a mixture of planning, translating, and reviewing as defined here. Hence, it may be that the present results and Gould's findings are not inconsistent, once operational definitions are taken into account.

Translating required less effort than did either planning or reviewing in Experiment 1 but not in Experiment 2. Although the interference scores stayed about the same from Experiment 1 to Experiment 2 for translating [overall mean of 317 vs. 289, $t(88) < 1.0$], they dropped significantly ($p < .05$) for planning (366 vs. 295, $t(88 = 2.37$] and reviewing [359 vs. 290, $t(88) = 2.09$]. Planning and, to a lesser extent, reviewing were expected to require considerable effort because of the complex subprocesses involved and because of a lack of extensive relevant practice. Translating was anticipated to require less effort because of the extensive practice associated with translating ideas into spoken language. Experiment 1 supported the latter prediction and showed that reviewing can be just as demanding as planning. Experiment 2 showed that planning and reviewing can drop in their effort demands to the same low level as translating.

It is important to note, however, that all of the processes, including translating, revealed sizable expenditures of cognitive effort in both experiments. A review of the relevant literature indicated that these levels of effort are comparable to those seen in the complex task of playing chess and are markedly greater than those seen in reading and verbal learning tasks (Kellogg, 1986).

It is tempting to look for task differences that might account for the variations across experiments. The United Nations task may have elicited greater involvement, because of the emotionally charged atmosphere surrounding the Korean airliner shooting, than did the other tasks.

Consistent with this speculation, the absolute level of cognitive effort tended to be greater overall in Experiment 1 than in Experiment 2 [$t(88) = 1.96, p < .06$]. Perhaps with relatively unengaging tasks, planning and reviewing do not involve the high levels of effort that they do in tasks of great interest to the writer.

In both experiments, high-knowledge conditions resulted in the expenditure of less cognitive effort than did low-knowledge conditions. Manipulating topic knowledge in a writing task yields support for the workload hypothesis and contradicts the prior knowledge hypothesis developed in other contexts. These results support, in the case of topic knowledge, the theoretical contention (Flower & Hayes, 1980b; Nold, 1981) that knowledgeable writers lessen the mental workload of writing by performing some operations relatively automatically. Presumably, manipulations of language and audience knowledge would produce a similar conclusion.

The precise nature of the task may determine whether high knowledge of a topic increases or decreases the expenditure of effort relative to low knowledge. Britton et al. (1979) and Britton and Tessor (1982) have convincingly demonstrated that for reading tasks the expenditure of effort conforms to the predictions of the prior knowledge hypothesis. The present findings for writing tasks seem equally compelling in support of the workload hypothesis. Additional work is needed to specify why the pattern differs across tasks.

Interestingly, knowledge of the writing topic did not affect the writer's strategy for allocating either processing time or cognitive effort to planning, translating, and reviewing. It was anticipated that a writer who knew the topic well would elect to devote less time to planning and reviewing and more time to translating than would a less knowledgeable writer. This failed to occur in any of the three phases of drafting investigated here. Also, because topic knowledge is central to generating and organizing ideas, it was expected that planning would show a greater difference in effort expenditure between low- and high-knowledge subjects than would translating and reviewing. Yet no interactions between topic knowledge and type of process were observed in the processing time and effort data, even when a large sample size ($n = 30$ in Experiment 2) was tested to guarantee adequate statistical power.

It would be worth knowing if language and audience knowledge similarly fail to interact with process type. Such an outcome would imply that a writer's knowledge in general does not guide how resources are divided among processes. The relative amounts of processing time and cognitive effort given to planning, translating, and reviewing may instead be primarily controlled by the demands of the task. As noted previously, task differences suggest one account of the variations in how cognitive effort was allocated to planning, translating, and reviewing and in how knowledge affects overall effort expenditure.

REFERENCES

Applebee, A. N. (1982). Writing and learning in school settings. In M. Nystrand (Ed.), *What writers know*. New York: Academic Press.

Atlas, M. (1979, December). *Addressing an audience: A study of expert-novice differences in writing* (Tech. Rep. No. 3). New York: American Institutes for Research.

Beach, R., & Bridwell, L. S. (Eds.). (1984). *New directions in composition research*. New York: Guilford.

Benton, S. L., Kraft, R. G., Glover, J. A., & Plake, B. S. (1984). Cognitive capacity differences among writers. *Journal of Educational Psychology*, **76**, 820-834.

Bobrow, J. (1979). *Barron's new guide to the Law School Admissions Test*. Woodbury, NY: Barron's Educational Series.

Boice, R. (1985). Cognitive components of blocking. *Written Communication*, **2**, 91-104.

Bridwell, L., Johnson, P., & Brehe, S. (1986). Composing and computers: Case studies of experienced writers. In A. Matsuhashi (Ed.), *Writing in real time: Modelling production processes*. London: Longman.

Britton, B. K., Holdredge, T. S., Curry, C., & Westbrook, R. D. (1979). Use of cognitive capacity in reading identical texts with different amounts of discourse level meaning. *Journal of Experimental Psychology: Human Learning and Memory*, **5**, 262-270.

Britton, B. K., & Tessor, A. (1982). Effects of prior knowledge on use of cognitive capacity on three complex cognitive tasks. *Journal of Verbal Learning & Verbal Behavior*, **21**, 421-436.

Charney, D. (1984). The validity of using holistic scoring to evaluate writing: A critical overview. *Research in the Teaching of English*, **18**, 65-81.

Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science*, **5**, 121-152.

Cowley, M. (1957). *Writers at work: The* Paris Review *interviews*. New York: Viking.

Daiute, C. A. (1984). Performance limits on writers. In R. Beach & L. S. Bridwell (Eds.), *New Directions in Composition Research* (pp. 205-224). New York: Guilford.

de Beaugrande, R. (1980). *Text production*. Norwood, NJ: Ablex.

Ericsson, K. A., & Simon, H. A. (1980). Verbal reports as data. *Psychological Review*, **87**, 215-251.

Faigley, L., & Miller, T. P. (1982). What we learn from writing on the job. *College English*, **44**, 557-559.

Flower, L., & Hayes, J. R. (1980a). The cognition of discovery: Defining a rhetorical problem. *College Composition & Communication*, **2**, 21-32.

Flower, L., & Hayes, J. R. (1980b). The dynamics of composing: Making plans and juggling constraints. In L. W. Gregg & E. R. Steinberg (Eds.), *Cognitive processes in writing* (pp. 31-50). Hillsdale, NJ: Erlbaum.

Flower, L., & Hayes, J. R. (1984). Images, plans, and prose: The representation of meaning in writing. *Written Communication*, **1**, 120-160.

Frederiksen, C. H., & Dominic, J. F. (Eds.). (1981). *Writing: Process, development, and communication* (Vol. 2). Hillsdale, NJ: Erlbaum.

Freedman, S. W., & Calfee, R. C. (1983). Holistic assessment of writing: Experimental design and cognitive theory. In. P. Mosenthal, L. Tamor, & S. A. Walmsley (Eds.), *Research in writing: Principles and methods* (pp. 75-98). New York: Longman.

Glynn, S. M., Britton, B. K., Muth, D., & Dogan, N. (1982). Writing and revising persuasive documents: Cognitive demands. *Journal of Educational Psychology*, **74**, 557-567.

Gould, J. D. (1978). How experts dictate. *Journal of Experimental Psychology: Human Perception & Performance*, **4**, 648-661.

Gould, J. D. (1980). Experiments on composing letters: Some facts, some myths, and some observations. In L. W. Gregg & E. R. Steinberg (Eds.), *Cognitive processes in writing* (pp. 97-127). Hillsdale, NJ: Erlbaum.

Graesser, A. C., Hopkinson, P. L., Lewis, E. W., & Bruflodt, H. A. (1984). The impact of different information sources on idea

generation: Writing off the top of our heads. *Written Communication*, **1**, 341-364.

GREEN, D. W., & WASON, P. C. (1982). Notes on the psychology of writing. *Human Relations*, **35**, 47-56.

GREEN, G. M., & MORGAN, J. L. (1981). Writing ability as a function of the appreciation of differences between oral and written communication. In C. H. Frederiksen & J. F. Dominic (Eds.), *Writing: Process, development, and communication* (Vol. 2, pp. 177-188). Hillsdale, NJ: Erlbaum.

GREGG, L. W., & STEINBERG, E. R. (Eds.). (1980). *Cognitive processes in writing*. Hillsdale, NJ: Erlbaum.

GROFF, P. (1978). Children's oral language and their written composition. *Elementary School Journal*, **78**, 181-191.

GUILFORD, J. P. (1967). *The nature of human intelligence*. New York: McGraw-Hill.

HAYES, J. R., & FLOWER, L. S. (1980). Identifying the organization of writing processes. In L. W. Gregg & E. R. Steinberg (Eds.), *Cognitive processes in writing* (pp. 3-30). Hillsdale, NJ: Erlbaum.

KAHNEMAN, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice-Hall.

KELLOGG, R. T. (1986). Designing idea processors for document composition. *Behavior Research Methods, Instruments, & Computers*, **18**, 118-128.

KENNEDY, M. L. (1985). The composing process of college students writing from sources. *Written Communication*, **2**, 434-456.

KERR, B. (1973). Processing demands during mental operations. *Memory & Cognition*, **1**, 401-412.

MILLER, G. A., GALANTER, E., & PRIBRAM, K. H. (1960). *Plans and the structure of behavior*. New York: Holt, Rinehart, & Winston.

NOLD, E. W. (1981). Revising. In C. H. Frederiksen & J. F. Dominic (Eds.), *Writing: Process, development, and communication* (Vol. 2, pp. 67-80). Hillsdale, NJ: Erlbaum.

NYSTRAND, M. (Ed.). (1982). *What writers know*. New York: Academic Press.

ODELL, L., & GOSWAMI, D. (1984). Writing in a nonacademic setting. in R. Beach & L. S. Bridwell (Eds.), *New directions in composition research*. New York: Guilford.

ROSE, M. (ED.). (1985). *When a writer can't write*. New York: Guilford.

SCHUMACHER, G. M., KLARE, G. R., CRONIN, F. C., & MOSES, J. D. (1984). Cognitive activities of beginning and advanced college writers: A pausal analysis. *Research in the Teaching of English*, **18**, 169-187.

SOMMERS, N. I. (1979). The need for theory in composition research. *College Composition and Communication*, **30**, 46-49.

STEIN, M. I. (1974). *Stimulating creativity: Vol. 1. Individual procedures*. New York: Academic Press.

TAYLOR, C. W., & BARRON, F. (Eds.) (1963). *Scientific creativity: Its recognition and development*. New York: Wiley.

TYLER, S. W., HERTEL, P. T., MCCALLUM, M. C., & ELLIS, H. C. (1979). Cognitive effort & memory. *Journal of Experimental Psychology: Human Learning & Memory*, **5**, 607-617.

VOSS, J. F., VESONDER, G. T., & SPILICH, G. J. (1980). Text generation and recall by high-knowledge and low-knowledge individuals. *Journal of Verbal Learning & Verbal Behavior*, **17**, 651-667.

WOODRUFF, E., BEREITER, C., & SCARDAMALIA, M. (1981-82). On the road to computer assisted instruction. *Journal of Educational Technology Systems*, **10**, 133-149.

NOTES

1. Vocal responses to auditory probes were selected to avoid decrements in primary task performance. The use of other common secondary tasks (e.g., keypress responses to visual stimuli or continuous tapping) were precluded because the subjects had to be able to move their hands and eyes freely while composing. Undoubtedly, these other tasks would interfere with writing performance. Although it is ideal to use more than one secondary task to ensure that secondary task interference reflects cognitive effort and not structural interference alone (Kahneman, 1973), such a precaution was not practical here or in the complex tasks studied by Britton and Tessor (1982). Selecting a task that is low in structural interference seemed to be a reasonable alternative.

2. WPM is only a rough summary of overall composing rate. Writers typically vary their speed markedly: They write in spurts and then pause. Although a study of these changes in rate is worthwhile, the present research was not designed to address such issues.

3. Interjudge reliability was checked by computing Pearson's r. The coefficients were moderate but significant ($p < .05$) for all scales: Language usage (.56), organizational coherence (.57), idea development (.45), effectiveness (.50), and mechanics (.69). This level of agreement was anticipated given the complexity of the judgment process (Freedman & Calfee, 1983) and similar levels of reliability reported elsewhere in the writing literature (Woodruff, Bereiter, & Scardamalia, 1981-82).

4. The interjudge reliability coefficients were again all significant but moderate in size: language usage (.62), organizational coherence (.56), idea development (.49), effectiveness (.63), and mechanics (.51).

5. To determine whether the retrospective probes interfered with writing, we used the writing task of Experiment 1 to examine a control group of 30 subjects. Those in the control group wrote without any interruptions. An analysis of efficiency and quality measures revealed no differences between the control group and the 30 subjects of Experiment 1. Hence, the procedure was unintrusive.

6. Retrospection is more informative than pause analysis if it offers valid insights into the writer's actual thought processes. That is, did the subject use the four response categories in the manner intended by the experimenter? Although this is difficult to ascertain, a pilot experiment was conducted to check the validity assumption. The logic of the assessment was to compare how the experimenter and the subject categorized a record of the subject's thoughts while composing. The record consisted of an undirected verbal protocol. Twelve subjects were asked to write documents while thinking aloud into a tape recorder at 1-min intervals. Immediately after a subject had spoken, the experimenter covertly categorized each segment as an example of planning, translating, reviewing, or unrelated activity. Next, the subjects were trained to use the retrospective method employed here (requiring 15 min) and then were asked to categorize the segments of their own verbal protocols by listening to the tape recording.

The subjects' categorizations were compared with the experimenter's. If the method is valid, then one would expect agreement between these categorizations. Overall, 82% of the categorizations were in agreement. This figure is substantial in light of the difficulties the experimenter experienced in categorizing brief segments of verbal protocols and the 15-min delay between the writer's thinking aloud while composing and going back to categorize each segment of the verbal protocol.

(Manuscript received March 17, 1986;
revision accepted for publication September 4, 1986.)