Journal of Applied Psychology
1985, Vol. 70, No. 2, 264–271

0021-9010/85/$00.75

Anticipatory Processing in Transcription Typing

Timothy A. Salthouse
University of Missouri

Three measures assessing the extent of advance preparation employed during normal transcription typing were obtained from 29 typists ranging in skill from 18 to 113 net words per minute. It was found that the typists could continue to type about 13 characters after the sudden disappearance of the text display. However, when the amount of visible text was progressively reduced, noticeable disruptions of typing rate were not evident until the display contained fewer than 5 characters. These differences were attributed to how much one *reads* versus how much one *needs* when typing from printed text. A third measure of preparation, the maximum sequence of characters found to affect the distribution of interkey intervals, averaged about 2 characters and was attributed to the size of the response execution buffer.

How far in advance of the current keystroke does a skilled typist exhibit preparation for forthcoming keystrokes? Although this seems a simple and straightforward question, quite different answers are available depending on the vocational interests of the person to whom the question is addressed, the kind of typing to which one refers, and the specific level of information processing within the typing sequence. For example, instructors and others with a pedagogical interest in typing often maintain that fast typing is achieved only by considering and processing the to-be-typed material in terms of words or entire phrases (Book, 1925; Clem, 1955; Dvorak, Merrick, Dealey, & Ford, 1936; Lessenberry, Crawford, & Erickson, 1967). On the other hand, a number of recent typing researchers have argued that the functional unit of typing is seldom larger than two or three keystrokes (e.g., Logan, 1982; West & Sabban, 1982). This discrepancy may, at least in part, be based on a difference in purpose or perspective. From the instructional perspective the goal is to facilitate and motivate the acquisition of typing skill by suggesting useful strategies for approaching the task of typing, whereas the research perspective is primarily concerned with specifying as precisely as possible the characteristics of a narrow class of behavior.

The dependence of the answer on the kind of typing originates because at least two major classes of typing activity can be distinguished—transcription typing and composition typing. The former takes place when the typist merely has to transcribe handwritten, typed, or auditory material into typed copy. Composition typing, on the other hand, occurs when the typist is composing at the keyboard, and attempting to organize thoughts, consider alternative phrasings, and so forth, interspersed with periods of keystroke activity during which the ideas are translated into typed copy. Preparation, in one form or another, is likely to be much more extensive in composition than in transcription typing because general notions of the purpose of the composition must be maintained throughout the typing session. That is, if the cognitive activities of planning and organizing one's composition are considered preparation for typing, then the amount of preparation may extend to paragraphs or even complete pages. In order to reduce the investigative problem to a manageable level, the focus in the current study will be restricted to transcription typing.

The issue of processing level arises because several conceptually distinct types of information processing are likely to be involved in the activity of transcription typing. For example, according to a recent model (Salthouse, 1984b), transcription typing progresses

This research was supported by a Research Career Development Award (NIA 1K04 AG00146-01A1) to the author.

Please address reprint requests to T. Salthouse, Department of Psychology, McAlester Hall, University of Missouri, Columbia, Missouri 65211.

in four stages labeled, in succession, input, parsing, translation, and execution. The input stage is responsible for forming easily remembered chunks from the to-be-typed material, and in the parsing stage these chunks are decomposed into a sequence of discrete characters. The characters are converted into movement specifications by the translation stage, and then these specifications are actually implemented as overt movements in the execution stage. Although the stages are necessarily sequential for a given character, it is assumed that they can overlap for different characters, and in fact the amount of simultaneity or overlap of processing is postulated to be a major determinant of a given typist's level of skill.

If typing truly proceeds in a sequence of stages such as that outlined above, it is obvious that quite different estimates of the amount of anticipatory processing could be obtained by focusing on measures reflecting the operation of different stages of processing. An implication of this fact is that the interpretation of measures of preparation in typing requires a relatively explicit model of the processes involved in typing, along with a specification of which particular processes are responsible for which measures. In the present report, three different estimates of preparation in transcription typing are derived and interpreted in the context of the model outlined above. The three preparation measures are similar to the three typewriting spans discussed by Logan (1983), but, unlike prior studies, all are obtained from the same individuals to allow comparisons of the interrelations between measures.

One estimate of how far ahead of the current keystroke typists are processing information from the to-be-typed material is what Rothkopf (1980) has called the copying span. The technique Rothkopf employed to determine the copying span involved monitoring the typists' inspections of the text material and counting the number of characters typed between successive glances at the material. The five highly skilled typists in his study typed an average of about 40 characters between inspections of the to-be-typed material, indicating that they had a copying span of approximately eight words. A conceptually analogous technique for assessing copying span used in the present study involves determining how many characters can continue to be typed correctly after the removal of the to-be-typed material. This procedure is similar to that used to measure eye-voice span in oral reading (e.g., Levin, 1979), but it has apparently not previously been used in studies of typing. Typical values of eye-voice span are between four and five words (20 to 25 characters) in readers of average ability. (The discrepancy between the estimates from Rothkopf's procedure and those from the eye-voice span are probably attributable to the subjects in the Rothkopf study relying on maximum, instead of typical, capacities because they were prevented from looking at the text while typing.)

Copying span has its origins in the input operations of the model in that it is assumed to reflect the chunked output of the initial stage of input processing. The input phase in typing is presumed to be similar to an early stage in reading and thus the chunks are likely to be based on familiar reading units, with their number determined by the size of the individual's working memory capacity.

A second estimate of the extent of anticipatory processing during typing is available in a measure termed the eye–hand span. This measure corresponds to the number of characters intervening between the character whose key is currently being pressed and the key receiving the attention of the eyes. Eye–hand span has been assessed directly by recording eye movements when a person is typing, and then synchronizing the eye movement and typing records to determine the position of the eye at the time of each keystroke. Butsch (1932) has used this technique and reported that, among average typists, the eyes are generally about five characters ahead of the fingers. The present study employed an alternative technique for determining eye–hand span based on a restricted preview procedure in which the rate of typing is examined while systematically varying the amount of preview of the to-be-typed material. An estimate of the eye–hand span can be derived from the preview size at which the typing rate reaches its asymptotic speed. If the rate of typing is disrupted with less than this number of characters visible on the display, then it can be inferred that the typist relies on the availability of at least this many characters in normal typing. Hershman and Hillix (1965), Salthouse (1984a, 1984b), and Shaffer (1973) have all reported that between three and eight characters were needed for moderately skilled typists to achieve a typing rate equivalent to that produced with unlimited preview.

The eye–hand span is considered an adaptive mechanism whose purpose is to ensure efficient, uninterrupted processing concerned with the specification and execution of movement sequences. It is therefore postulated to originate in the parsing process as a consequence of the need for a continuous flow of information to the translation and execution operations.

The third measure of anticipatory processing to be examined in the present study is based on a procedure recently described and used by Gentner (1982). (See also, Shaffer, 1978.) Briefly, this technique involves examining the variability of the distribution of interkey intervals for a particular character as a function of the number of preceding contextual characters. The reasoning is that the overall distribution of interkey intervals is actually a composite of many narrower distributions, each specific to a particular sequence of prior keystrokes, and by progressively specifying more prior context the overall variability can be partitioned into successively smaller segments. The relevance to the present issue is that the number of constraint characters at which there is no further reduction in the variability of the interkey interval distribution can be considered an index of the amount of advance preparation.

Gentner (1982) found that six skilled typists exhibited an interquartile range of interkey intervals of 55 ms for no constraint, 32 ms when one preceding character was specified, 26 ms with two constraining characters, and 24 ms with three constraining characters. Because the reduction in variability from two to three constraining characters was very slight, Gentner concluded that his typists exhibited preparation for an average of two keystrokes ahead of the current keystroke.

According to the model, these context effects primarily originate in the translation and execution operations, and reflect the integration and coordination of spatio-temporal parameters for overt movements of the fingers and hands. The maximum sequence at which contextual effects are observed is assumed to provide an estimate of the buffer size of either the translation or the execution mechanisms in the model. That is, if there is an effect of context n characters in advance of a given character, then at least $n + 1$ translated response codes must be simultaneously available in the translation and/or execution mechanisms.

Three quite different procedures for estimating the amount of anticipatory processing in transcription typing are therefore available, and the model provides predictions of the relative magnitudes of the preparation estimates based on the processing stages at which each is assumed to be operative. The copying span is expected to average up to 25 characters because it reflects the activity of the input mechanism, the eye–hand span between three and eight characters because it reflects the activity of the parsing mechanism, and the constraining context to extend from one to two characters because this manipulation is assumed to influence the translation or execution mechanisms. The purpose of the present study is to confirm these expectations and also to examine the degree of interrelation among the alternative measures. Because typists of a wide range of skill levels participated in the project, an additional goal of the study was to determine the correlation between each measure and overall level of typing skill.

Method

Subjects

Twenty-nine touch typists, all with recent electric typewriter experience, participated in a single session of 1.5 to 2.5 hr. The typists ranged from 18 to 43 years of age (mean age = 27) and had an average of 14.5 years of formal education. The amount of recent typing experience varied from 0.5 to 55.0 hr per week (mean = 13.1), and the number of months employed with typing as a major activity of one's job ranged from 0 to 216 with a mean of 49.0.

Apparatus

All typing was performed on an Apple IIe microcomputer, which contained a Mountain Hardware real-time clock accurate to 10 ms. The keyboard on this computer is arranged like that of the popular IBM Selectric typewriter, and the typists generally reported that the feel was quite satisfactory.

Procedure

Each typist performed the same sequence of activities, beginning with straight transcription typing of paragraph 6 of the Nelson–Denny Form B Reading Test. This 1,262-character passage was to be typed in a normal fashion, that is, as rapidly and accurately as possible, and the typed copy appeared on the video monitor as it was produced. A primary purpose of this activity was to provide an evaluation of each individual's level of typing skill. The net words per minute (NWPM), which served as the index of typing skill, was computed by subtracting five keystrokes (one word) for every error, dividing the net keystrokes by five to yield net words, and then dividing this quantity by the number of minutes required to type the entire passage.

The next three activities were each performed twice in a counterbalanced sequence. The first consisted of typing a specially selected set of 192 words four times each, with the typed copy displayed on the video monitor as it was produced. A subset of 24 of the words is displayed in Table 1. Notice that the final letter remained constant across the varying amounts of context, but with each increase in constraint one additional letter to the left was specified and held constant. In addition to the words presented in Table 1, comparable sets of 24 words each were selected for seven other letter strings, each terminating in a different letter. Words from each set were randomly intermixed to encourage typing in as normal a fashion as possible.

The four exemplars at every context level for the eight strings were each typed four times, and therefore a total of 16 repetitions for each combination of string and context was available. The interquartile range of the distribution of 16 interkey intervals between the second-to-the-last character and the last character in each word served as the basic measure of variability. The median interquartile range across the eight strings was computed to yield a single index of variability for each typist at each level of contextual constraint. The critical value of contextual constraint, indicating the range of contextual sensitivity, was identified as the maximum amount of context consistent with a monotonically decreasing median interquartile range with increased context. For example, if the medians for contexts 0 through 5 were, respectively, 70, 40, 30, 40, 35, and 30 ms, the contextual sensitivity estimate would be 2, because the median interquartile range decreased from 70 ms with Context 0, to 40 ms at Context 1, to 30 ms with Context 2 but then increased or remained relatively stable with additional context.

Table 1
Examples of Words With Varying Amounts of Contextual Constraint

Constraint	Exemplars			
0	scalawag	underdog	firebug	foreleg
1	wrong	overhang	among	prolong
2	looking	dueling	beginning	meaning
3	reading	bleeding	preceding	evading
4	understanding	expanding	corresponding	funding
5	impending	defending	suspending	attending

The second activity was designed to provide a measure of the typists' eye–hand span. Material was presented on the video monitor and arranged such that each keystroke caused the text display to move one space to the left. No visible copy was produced in this task, but the amount of preview of to-be-typed material systematically varied with each successive 50 keystrokes. That is, the preview window initially contained 11 characters and then decreased by 2 characters with every 50 keystrokes until reaching a preview of 1 character. After 50 keystrokes with a preview of 1, the window increased to 2 and with each successive 50 keystrokes increased by an additional 2 characters until reaching a window of 10 characters, at which time the entire cycle was repeated until the end of the passage. The to-be-typed material consisted of Paragraphs 7 (for the first block) and 2 (for the second block) of the Nelson–Denny Form B Reading Test. These paragraphs contained 1,269 and 1,171 characters, respectively. The eye–hand span was determined by identifying the largest preview window, across both ascending and descending window sizes, at which the median interkey interval first exceeded the third quartile of the interkey interval from normal typing. In other words, the span was operationally defined as the maximum preview in which 50% of the interkey intervals were greater than 75% of the interkey intervals from normal typing. Because the keying rate with previews larger than this span amount was nearly identical to that in normal typing with unlimited preview (e.g., the correlation between the median interkey interval with an 11-character preview and that in normal typing was +.98), the interkey interval in normal typing was used as the asymptotic level from which deviations were determined.

The third and final typing activity was designed to provide a measure of the typists' copying span. The procedure involved presenting material on the video monitor using the leftward-moving display with a preview window fixed at 39 characters. After a predetermined number of keystrokes, the display was erased and the typist instructed to continue typing as much material as he or she was confident appeared on the display. The material consisted of eight sentences, movie descriptions from TV GUIDE magazine, with an average length of 75 characters. Two sentences each were typed with 15, 25, 35, and 45 keystrokes prior to the disappearance of the display. The median number of characters that were typed correctly after the blanking of the display served as the measure of copying span. (There was no effect of the number of keystrokes prior to the blanking of the display, and therefore this variable was ignored in subsequent analyses.)

Results

Net typing speed for the 29 typists ranged from 18 to 113 NWPM with a mean of 62.4. Gross speeds ranged from 20 to 120 words per minute with error percentages from 0.1 to 4.2. Typing skill (NWPM) correlated .48 ($p < .01$) with recent typing experience, .64 ($p < .01$) with the number of months em-

Table 2
First, Second, and Third Quartiles of the Distribution of Interkey Intervals (in milliseconds) for Three Kinds of Typing

Kind of typing	Quartile Q1	Q2	Q3
Normal typing	142	174	222
Random words	146	178	226
Horizontal scrolling	132	163	214

ployed as a typist, and .66 ($p < .01$) with age of the typist.

Table 2 contains a summary of the temporal characteristics of typing performance in three of the tasks. Normal typing was the meaningful passage typed to assess skill level, random words were the passages used to provide an estimate of contextual constraint, and horizontal scrolling was the typing in the copying span task prior to the disappearance of the material. The columns labeled Q1, Q2, and Q3 indicate, respectively, the first (25th percentile), second (50th percentile or median), and third (75th percentile) quartiles of the distribution of interkey intervals. Notice that performance was quite similar across all activities. The correlations (all $p < .01$) between the medians were .99 for normal versus random words, .98 for normal versus horizontal scrolling, and .98 for random words versus horizontal scrolling.

Figure 1 illustrates the mean of the median interkey intervals as a function of preview window for each of four speed groupings (six typists at less than 40 NWPM, $M = 27.8$; seven typists at between 40 and 60 NWPM, $M = 48.1$; eight typists at between 60 and 80 NWPM, $M = 72.5$; and eight typists with speeds greater than 80 NWPM, $M = 90.6$). An analysis of variance (ANOVA) revealed that the four groups differed significantly in the median interkey interval in normal typing, $F(3, 25) = 39.98$, $p < .01$, and in the median interkey interval with an 11-character preview, $F(3, 25) = 36.95$, $p < .01$. However, it is important to observe that the functions differ not only in asymptotic speed but also in the preview window at which that asymptotic speed was first achieved. The overall eye–hand span, determined for each individual according to the procedure described above, averaged 3.97 characters. The average spans for the four speed groups were, respectively, 2.17, 2.71, 4.88, and 5.50 characters, $F(3, 25) = 27.15$, $p < .01$. Newman-Keuls comparisons revealed that the two lowest values differed significantly from the two highest values, but the differences within these pairs were not significant. The correlation between NWPM and eye–hand span across all 29 typists was .85 ($p < .01$).

Figure 2 illustrates the means across the same speed groups of the median interquartile range as a function of the amount of constraining context. As was the case with the preview manipulation, the interesting question is not simply the difference in absolute levels across typists of varying speeds but the contextual constraint at which the median variability reached its asymptotic level. Faster typists had smaller interquartile ranges, as reflected in the correlations between net typing speed and median interquartile range of −.47 to −.68 (all $ps < .01$) across the six contextual constraints. However, the data of Figure 2 suggest that typists of all speed levels exhibit nearly the same amount of sensitivity to prior context because all groups reached a stable level of median variability with between 1.5 and 2.5 characters specified in advance of the critical character. (A similar pattern was evident when the standard deviation was used as the index of variability instead of the interquartile range.) The average critical contextual constraint was 1.76, and its correlation with NWPM was −.21 ($p > .25$). Mean values across the four speed groups were: 2.17, 2.00, 1.38, and 1.63 characters, respectively, in order of increasing speed, $F(3, 25) = 1.01$, $p > .40$.

The correlation between NWPM and the median number of characters typed after the disappearance of the test display (i.e., the copying span) was .35 ($.10 > p > .05$). Across all typists the copying span averaged 13.2 characters, and from the slowest to the fastest speed groups the spans averaged 10.5, 12.4, 15.5, and 13.6 characters, respectively, $F(3, 25) = 1.70$, $p > .15$.

Observation of the typists during the copying-span procedure suggested that they frequently ended their span with a complete word. Subsequent analyses confirmed this

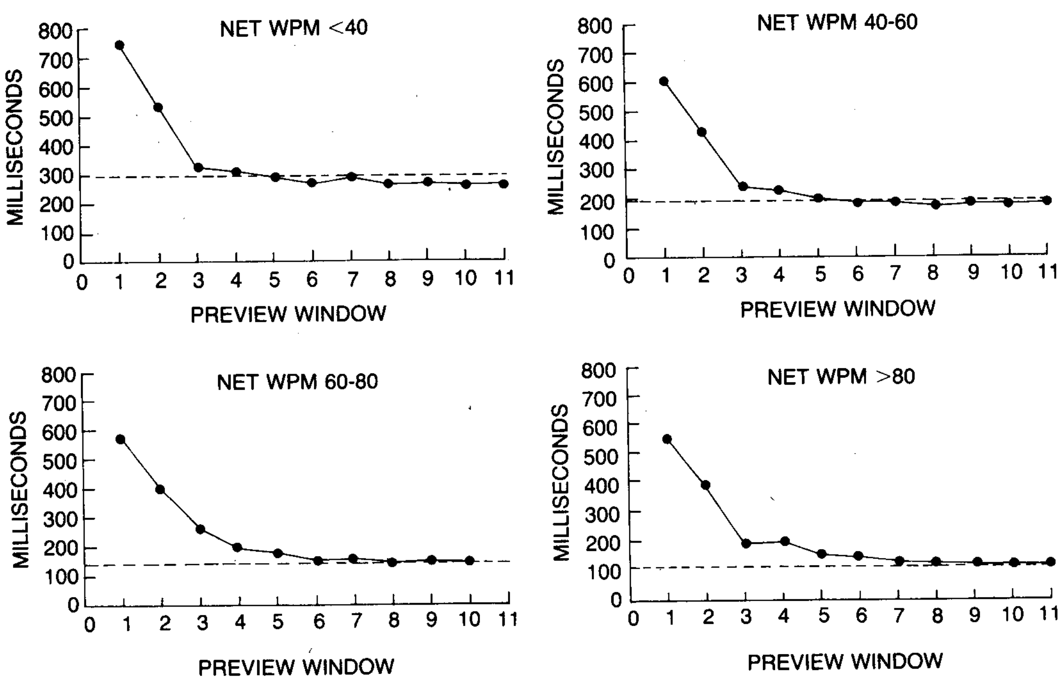

Figure 1. Mean of the median interkey interval as a function of preview window in four groups of typists of varying skill level. The dashed line in each panel represents the median interkey interval during normal typing with unlimited preview.

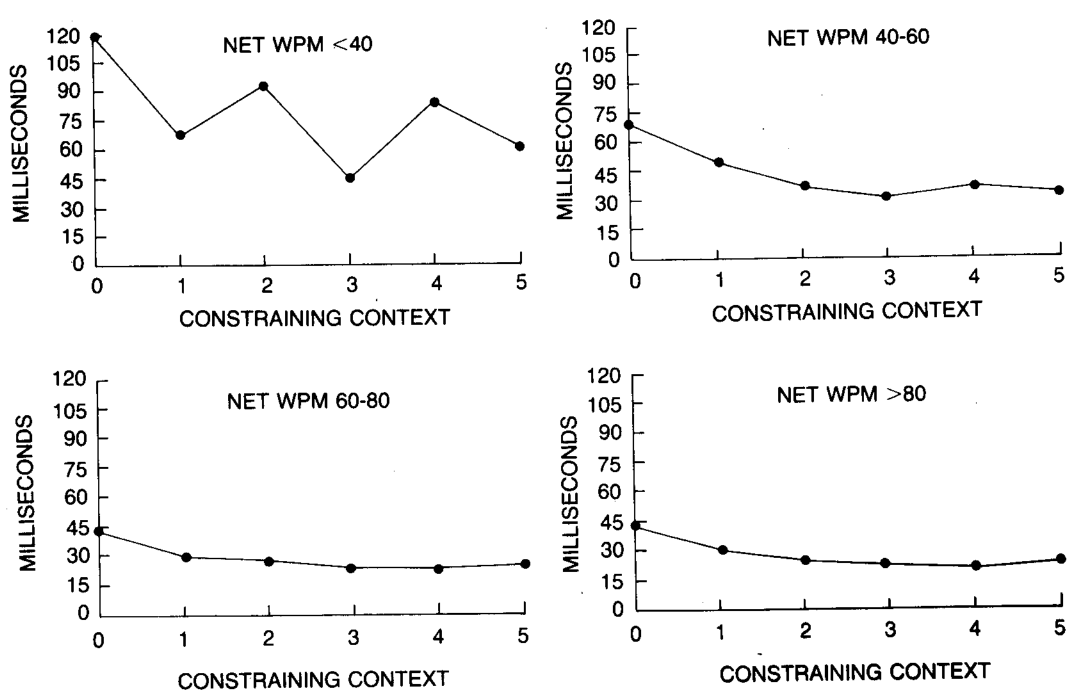

Figure 2. Mean of the interquartile range (Q3–Q1) of interkey intervals as a function of constraining context in four groups of typists of varying skill level.

observation in that 86.9% of the passages typed after the display was blanked ended in the complete word, and an even higher percentage ended in a word but one that was not correct, for example, "murder" in place of "murdering." The percentage of copying spans terminating in a complete word was not significantly related to typing skill ($r = .10$, $p > .50$).

For every typist the copying span was greater than the eye–hand span, and for 23 of the 29 typists eye–hand span was greater than the critical contextual constraint. Correlations between measures were .28 ($p > .10$) between copying span and eye–hand span, −.15 ($p > .40$) between copying span and critical contextual constraint, and −.01 ($p > .90$) between eye–hand span and critical contextual constraint.

Discussion

As predicted, the data of the present experiment provide three different answers to the question of how far in advance a typist prepares for future keystrokes. Typing can continue for an average of 13 characters after the to-be-typed material is removed from the display, indicating that the typists are aware of (or at least encode in some fashion) two to three words in advance of the current keystroke. However, if the number of characters simultaneously visible on the display is progressively reduced, noticeable changes in typing rate are not evident until fewer than about four characters are presented. This finding suggests that the typists are only using (i.e., actively processing or translating) material about one word beyond the current keystroke. And finally, examination of the relation between the number of contextual characters held constant prior to a particular keystroke and the variability in the time to make that keystroke revealed that variability decreased up to about two characters of context but remained constant with further contextual constraint. This result implies that preparation extends across a maximum of three keystrokes because the precision and consistency of a given keystroke is only influenced by the context provided by the immediately preceding two keystrokes.

Another interesting aspect of the current results is that the various measures of anticipatory processing were differentially sensitive to typing skill. Neither the copying span nor the critical contextual constraint was significantly related to net words per minute, but eye–hand span was positively correlated with typing speed. In fact, the slope of the regression equation relating net words per minute to eye–hand span was .06, indicating that eye–hand span increased by about 1.2 additional characters for every increase of 20 net words per minute. A similar relationship between eye–hand span and typing speed was reported by Salthouse (1984b), where a sample of 74 typists yielded a regression slope of .05 with a correlation of .51.

Both of these sets of results are consistent with the four-component typing model described in the introduction. Different estimates of the amount of advance preparation are obtained because each originates from a different processing component. Copying span is assumed to correspond to the product of the input mechanism, eye–hand span is assumed to reflect the operation of the parsing mechanism relative to the operation of the execution mechanism, and the critical contextual constraint is postulated to represent the contents of the translation or execution buffer. The finding that most of the subjects terminated their copying spans with a complete word suggests that the units of the input phase are whole words and may account for the introspective reports that typing appears to proceed in entire words with little or no awareness of discrete characters. Although the existence of three different measures of preparation necessitates only three distinct mechanisms, both a translation and an execution component are assumed to exist. One reason for postulating separate processes of this type is to account for the rapid detection of errors, which are presumably committed by the execution process but monitored and identified by the translation process.

The model accounts for the differential effects of skill on the three measures of preparation by assuming that increased skill primarily affects the synchronization of various operations rather than the efficiency of a single operation. That is, the eye–hand span increases with typing skill because of the need to ensure a continuous supply of information from the parsing process to the translation and execution processes. However, little or no skill-related change is evident in the amount of information grouped into chunks by the input mechanism, or in the amount of information simultaneously available in the execution buffer. The slight to nonexistent relation between typing skill and the size of the execution buffer is also confirmed in a study by Logan (1982). Typists in Logan's experiments were instructed to terminate their typing as quickly as possible upon the occurrence of a stop signal, and the average stopping span was found to be about 2.5 characters. In a later summary of these results, Logan (1983) reported that the correlation between typing speed and stopping span was a nonsignificant .20.

The results of the current study clearly indicate that there is no single answer to the question of how much in advance a typist prepares for forthcoming keystrokes. However, the findings are readily interpretable in the context of a model of transcription typing that distinguishes between four processing components corresponding to input, parsing, translation, and execution.

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Received July 30, 1984 ■