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# Multiple Spans in Transcription Typing

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Transcription typing has been postulated to consist of four components involving (a) input of chunks from the source text, (b) parsing of the chunks into discrete characters, (c) translation of the characters into movement specifications, and then (d) execution of those specifications in the form of keystroke responses. This multicomponent perspective on typing implies that it should be possible to identify distinct measures of anticipatory processing that correspond to the different processing components or spans. This prediction was tested, and largely confirmed, in three studies in which typists were administered a variety of experimental tasks to obtain span measures corresponding to the extent of anticipatory processing in different components of typing. As expected, the spans became progressively smaller as the hypothesized processing moved from input (with an average span of 8.1 characters) to execution (with an average span of only 1.4 characters).

In several recent articles, Salthouse (1984, 1985a, 1986) proposed that transcription typing involves the registration and coding of source text into easily remembered chunks by the input component, the partitioning or decomposition of the chunks into discrete characters by the parsing component, the conversion of characters into movement specifications by the translation component, and then those specifications implemented as keystrokes by the execution component. Although quite plausible arguments have been advanced for why each of these processing components might be necessary in transcription typing, there is still no direct evidence for their existence.

Salthouse (1985a) recently reported a study that attempted to investigate the existence of distinct processing components by using procedures to assess three different types of anticipatory processing, or spans. As expected, the three measures had considerably different magnitudes, with a measure termed *copy span* averaging 13.2 characters, a measure of eye–hand span 4.0 characters, and a measure of the sensitivity to constraining context only 1.8 characters. Although these results are consistent with a multicomponent model of transcription typing, it would have been more convincing to have had at least two independent measures of each postulated component. The present studies attempted to provide such evidence by obtaining measurements of five different types of processing spans during typing. The measures are described under the heading of the hypothesized component that they are presumed to be assessing.

## Input Component

As previously noted, the input process is postulated to be responsible for the initial registration of the source material into relatively familiar chunks. Two procedures were used to determine the amount of information available to the input process during transcription typing. One involved assessing the copy span in a manner similar to that described by Salthouse (1985a; i.e., by determining the average number of characters correctly typed after the unexpected disappearance of the display). However, unlike the procedure in previous study, predictability of the source text was minimized by using randomly arranged four-letter words as the stimulus material. (Previous research by Fendrick, 1937, Salthouse, 1985a, and West & Sabban, 1982, indicated that unrelated words are typed nearly as rapidly as meaningful text, and thus the use of this material was not expected to disrupt normal typing.)

The second measure of the information capacity of the input component was designated the *detection span*. It was assessed by determining how far in advance of the current keystroke the typist can detect a specially designated target character. If the target can be registered on the basis of features that do not require much processing, the number of characters intervening between the position of the target and the character currently being typed may serve as an index of when information first becomes available to the input process.

## Parsing Component

In the parsing phase it is assumed that individual characters are isolated from the larger verbal units (words or phrases) of the source text, or from the chunks held in the input process. Two procedures were used to examine processing during the parsing component—one assumed to correspond to when the parsing began and the other postulated to reflect when it ended. Because the rate of typing is slowed if parsing does not proceed rapidly enough to ensure a continuous supply of information to later processes (cf. Salthouse, 1984), the quantity assessed by the eye–hand span can be interpreted as an indication of how far in advance of the keystroke the source material is decomposed for subsequent processing.

An indication of when this parsing processing is completed can be obtained by determining the point at which the typist is

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insensitive to further alterations in the stimulus display. That is, if the source text is altered while the subject is typing and he or she does not respond to the alteration, then it can be inferred that the source text is no longer necessary for the processing of the character undergoing the alteration. The point at which typists relinquish further monitoring of the source text was termed the *replacement span*.

The stimulus display in the replacement span task was arranged such that certain critical target letters were replaced by other letters at varying distances in advance of the current keystroke. The instructions were to type the replaced character, and hence, if the typist continuously monitored the source text, he or she should always type the second character and never the first character. On the other hand, if the source is monitored only for a limited period of time, and then no longer consulted, the typist should frequently type the first rather than the second character, particularly if the replacement occurs in close proximity to the current keystroke.

The replacement interval that resulted in a 50% probability of typing the first character was defined as the replacement span and was hypothesized to indicate how far in advance of the keystroke the typist became committed to a particular character. Because the commitment presumably occurs as information is transmitted out of the parsing process, the replacement span was assumed to provide an estimate of the degree of anticipatory processing between the parsing and translation components of the model.

## Execution Component

Processing in the execution component is postulated to consist of the implementation of movement specifications transmitted from the translation component. The number of units in the execution component during normal typing can be assessed with a *stopping span* procedure introduced by Logan (1982), in which typists were instructed to immediately stop typing on the occurrence of a specially designated stop signal. Characters that continue to be typed after the occurrence of the stop signal can be interpreted as reflecting the contents of the execution component because these keystrokes are apparently no longer subject to interruption or modification.

Two independent studies were conducted, but because both involved similar procedures they are described together. However, one important procedural difference between the two studies was introduced based on an observation derived during the conduct of the first study. Because of the ease with which the skilled typists handled several of the special tasks, we suspected that they might have more reserve processing capacity than less skilled typists to devote to complying with the additional requirements while still performing normal typing. If this suspicion were correct, the span estimates for these individuals could be misleading because the values might simply reflect the ability to perform concurrent tasks while typing, and not the true sizes of the relevant component buffers. This excess capacity hypothesis was investigated by administering a simple reaction-time task, both alone and simultaneously with normal typing. If faster typists have more reserve capacity available for additional processing than do slower typists, they should exhibit less disruption of their reaction-time performance when switching from the single- to the dual-task conditions.

Typists from a wide range of age groups were used to increase the generality of the results and also to pursue an intriguing finding from an earlier study. Salthouse (1984) reported that older typists were able to maintain proficient levels of typing performance despite age-related declines in the efficiency of component processes, apparently because they relied on more extensive anticipation of forthcoming keystrokes than did young typists. Only the eye–hand span measure of anticipatory processing was available in the earlier study, however, and it is of interest to determine whether a similar compensatory effect is apparent with other measures of preparatory processing.

# Method

### Subjects

*Study 1.* Forty-five typists between 18 and 70 years old each received $10 to participate in a single session of between 1.5 and 2 hr. All were experienced electric-typewriter touch typists with a mean of 10.0 hr of typing per week over the last 6 months, and a range of 0 to 35 hr. The mean number of months employed with at least 10 hr per week of typing was 68.3 months, with a range of 0 to 288 months.

*Study 2.* Forty electric-typewriter touch typists between 18 and 64 years old each received $10 to participate in a single session of between 1.5 and 2 hr. They had a mean of 10.5 hr of typing per week over the last 6 months, with a range of 0 to 45 hr, and had been employed in positions involving at least 10 hr per week of typing, for an average of 101.5 months, with a range of 0 to 408 months. None had participated in the previous study.

### Apparatus

All typing was performed on an Apple IIe microcomputer with a hardware clock to allow recording of keystroke intervals to a resolution of 10 ms. The keyboard arrangement on this computer is very similar to that of the popular IBM Selectric typewriter, and the typists generally reported that the feel was quite satisfactory.

### Procedure

*Study 1.* Five different typing tasks were each performed twice in a counterbalanced order with a sixth task, the Digit Symbol Substitution subtest from the Wechsler Adult Intelligence Scale (Wechsler, 1958), administered between the first and second sequence of the five tasks. The purpose of the Digit Symbol test was to assess the representativeness of the subjects by allowing a comparison of age trends with previously published results.

Task 1, preceded by several minutes of practice to become familiar with the keyboard and typing in the manner requested, was normal typing from printed copy. The typing was to be performed as rapidly and accurately as possible, but the (carriage) return key was not to be pressed because the typed copy, which was visible on the display monitor, would automatically wrap around to the next line. Furthermore, no attempt was to be made to correct errors. The typing selections were paragraphs 6 and 2 (for the first and second administration of the task, respectively) from Form B of the Nelson-Denny Reading Test (Nelson & Denny, 1960). These passages (and paragraphs 4 and 7 used in Study 2), contained between 1,179 and 1,270 characters, including normal punctuation and capitalization.

Tasks 2 through 5 each involved the assessment of a different form of typing span and in order to maximize comparability, the same type of stimulus material—randomly arranged four-letter words—was used in each task. The to-be-typed material was displayed on a single line of the video monitor and arranged such that each keystroke caused the displayed material to move one space to the left. No visible copy was produced in these tasks, and the impression from the perspective of the typist was of controlling the rate of a leftward-scrolling marquee. A practice phase was administered in each task to ensure that subjects fully understood the instructions.

Task 2 was designed to assess what was termed the typist's copy span. The following instructions were given to the subjects in this task:

> Now you will be typing randomly arranged words that will be displayed on the monitor; you will not be able to see what you have typed. Type what appears on the screen in as normal a fashion as possible. At certain points the screen will go blank, and you should continue typing as much as you were sure was on the screen. After you can't remember any more of the material that was on the screen, press the '/' key to have the display reappear and resume typing. Remember to try to type as normally as possible.

A total of 35 characters were always visible on a line, and the display was blanked 10 times at random intervals ranging from 10 to 40 characters throughout the 500-character (100 4-letter words separated by spaces) passage.

Task 3 was designed to assess the typist's eye–hand span, with a procedure very similar to that used by Salthouse (1985a). Instructions were as follows:

> Now the material will always be visible on the screen, but the number of characters will be systematically varied from 11 down to 1. You will probably find typing with only a few characters visible rather strange, but try to type as normally as possible. The number of visible characters will decrease and increase several times as you type, but always just try to type normally.

The passage in this task consisted of 1,000 characters (200 words), with the visible window changing by 2 characters with every 25 keystrokes, first decreasing from 11 to 1, and then increasing from 2 to 10, decreasing again from 11 to 1, and so forth.

The fourth task was used to obtain an estimate of the typist's detection span. Task instructions were as follows:

> In this task a large number of characters will always be visible on the display, but occasionally a capital letter will appear. Whenever you notice a capital letter anywhere on the line you should press the '/' key as soon as you can and then resume typing. The capital letters should not be typed as capitals, but whenever you detect an upper-case letter you should press the '/' key. Always try to type as normally as possible.

A total of 20 targets appeared randomly with from 10 to 40 intervening characters throughout the 500-character (100-word) passage, and 35 characters were always visible on the line.

Task 5 was designed to measure the replacement span. The following instructions were used to introduce this task:

> In this task the material will always be lower case, but on some occasions a letter will be changed in the display. You should ignore the original character when this happens and type the "corrected" version that appeared most recently on the display. Remember to try to type exactly what appears on the screen in as normal a fashion as possible.

A total of 40 target letters were replaced during the 625-character (125-word) passage in this task. The number of visible characters was always 35, but the critical letter was replaced either 3, 5, 7, 9, or 11 characters to the right of the left edge of the screen. The new letter string created by the replaced character was always a word, and each letter position occurred equally often as the target (i.e., the first letter was replaced as often as the second, third, and fourth letters).

*Study 2.* Six tasks were performed twice, each in a counter-balanced order with the Wechsler Digit Symbol Substitution (Wechler, 1958), subtest administered between the first and second sequence of tasks. Tasks 1 (normal typing) and 6 (detection span) were identical to those of Study 1, and the replacement span task (Task 5) differed only with respect to the range of replacement intervals and the length of the passage. The replacement intervals ranged from 1 to 7 rather than from 3 to 11, and the passage length was doubled from 625 to 1,250 characters (125 to 250 words). These changes were considered desirable because the results from Study 1 indicated that the replacement spans were generally less than 5 characters, but the previous procedure included only one interval less than 5 characters.

The second task was an auditory reaction-time task in which responses were made by pressing a foot pedal containing a micro-switch. A total of 30 tone signals were presented in a block, with intervals between signals ranging from 2 to 6 s.

Task 3 was a composite of Tasks 1 and 2 in that subjects typed from printed copy while responding to auditory signals with foot pedal responses. The typing task was stressed both by instructions and by delaying the introduction of the concurrent reaction-time task until subjects had typed for about 30 s.

Task 4 was designed to assess the typist's stopping span. The procedure and stimulus materials were identical to the copying span task of Study 1, except that the typist was instructed to stop typing as quickly as possible upon the disappearance of the display.

## Results

Typing skill was assessed in terms of net typing speed, derived by subtracting five characters (one word) for each error from the gross number of keystrokes typed, 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 mean net words per minute (wpm) across the 45 typists of Study 1 was 57.0, with a range from 23.5 to 85.3, and that for the 40 typists of Study 2 was 58.6, with a range from 18.4 to 111.5. Gross typing speeds uncorrected for errors, which were correlated .99 with net typing speeds in both studies, ranged from 25.4 to 91.7 wpm in Study 1, and from 21.9 to 122.6 wpm in Study 2, with means of 61.1 and 63.1, respectively. Because the net measure incorporates both speed and accuracy and is the measure most often used to represent typing skill outside the laboratory, all subsequent analyses are based on this measure.

The means and standard deviations across typists of the median interkey intervals (in ms) in the different conditions of the two studies are presented in Table 1. (The values for the eye–hand span task are not represented because the interkey interval varies systematically with the size of the preview window, which increased and decreased while the typist was performing in this task.) Typing rate was somewhat slower in each of the experimental conditions than in normal typing, but at least some of the rate reduction may be attributable to the frequent pauses mandated by the requirements to make special detection or restart responses.

Separate span measures were derived for each typist in both administrations of every task. The median number of characters typed after the disappearance of the display served as the estimate of the span in both the copy span and stopping span tasks.

Table 1
*Means and Standard Deviations Across Subjects of Median Interkey Intervals*

| Interval | Study 1 *M* | Study 1 *SD* | Study 2 *M* | Study 2 *SD* |
|---|---|---|---|---|
| Normal typing | 182 | 52 | 181 | 64 |
| Concurrent typing | — | — | 185 | 62 |
| Detection span | 223 | 61 | 217 | 66 |
| Copy span | 206 | 61 | — | — |
| Replacement span | 209 | 53 | 203 | 63 |
| Stopping span | — | — | 201 | 65 |
| Reaction time | | | | |
| Alone | — | — | 269 | 49 |
| Concurrent | — | — | 431 | 85 |

The detection span was defined as the median number of characters intervening between the target and the character currently being typed. In other words, if on three separate occasions the target was detected when it was 12, 9, and 8 characters in advance of the leftmost character on the display, the detection span would be 9.

The eye–hand span was determined by first computing the median interkey interval at each preview window from 1 to 11, and then defining the eye–hand span as the largest window at which the median interval for that and all smaller windows was greater than the largest median across window sizes of 9, 10, and 11 characters. A somewhat different procedure was used in earlier studies (e.g., Salthouse, 1984, 1985a), but the present procedure was a convenient means of obtaining estimates from a single administration of the task, and informal comparisons indicated that it yielded values comparable to those derived from the previous procedures.

Replacement span was determined by computing the percentage of replaced (second) characters typed at each replacement interval, and then designating the span as the interval corresponding to a .5 probability of typing the replaced character.

Figure 1 portrays the frequency of typists with spans of each magnitude in Studies 1 and 2. Notice that the distributions are distinct and ordered in the manner one would expect if the spans reflected the operation of components becoming progressively more committed to a specific keystroke. In particular, note that the copy span was larger than the eye–hand span (a trend evident in 87% of the subjects for whom both measures were available), and the replacement span was larger than the stopping span (evident in all of the subjects for whom both measures were available). Detection span was expected to be larger than the replacement span but comparable to the copy span, and the results were generally consistent, as 80% of the typists had larger detection spans than replacement spans, whereas only 64% had detection spans larger than copy spans.

An alternative means of portraying the relations among the various anticipation measures is illustrated in Figure 2. The functions in this figure are based on data collapsed across all typists in a given study, and with the exception of the eye–hand span data that did not lend themselves to a representation in terms of probability, each represents a different type of probability. In the detection task the probability is that of detecting the target by the indicated character position. Data points from right to left correspond to the cumulative probability that a target at that position, or one to the right of that position, will be detected. The functions for the copy span and stopping span tasks are also based on cumulative probabilities, in this case the probability that the typing will continue to at least the indicated character position. Data points for the replacement span task correspond to the probability that the original character will be typed instead of the replaced character.

An advantage of expressing the span results in a format like Figure 2 is that it represents the different anticipation measures along common axes and thus facilitates comparison of relative magnitudes. That is, this figure makes it clear that there are distinct differences between the probability of continuing to type with instructions to type as much as possible and the probability of continuing to type with instructions to stop as quickly as possible, and between both of those probabilities and the probability of detecting and responding to a change in the stimulus display. Moreover, the mean eye–hand span displayed in Figure 2 suggests that it is intermediate between the replacement span on the one hand, and the copy and detection spans on the other hand.

Several performance measures were obtained in the reaction-time tasks, beginning with the median of the 30 reaction times in each administration in the single- and dual-task conditions. The means of these medians are displayed in Table 1, along with the means of the median interkey intervals in normal typing alone, and normal typing with the concurrent reaction-time task. Typing errors increased from 1.6% to 2.2% from the single- to the dual-task conditions, but net typing speed only changed from 58.6 to 53.8 wpm. Moreover, typists at all skill levels exhibited comparable effects on typing performance because the correlation between typing skill (in net wpm) and ratio of typing performance (dual/single) was only .12. Because the greatest effect of the requirement to divide one's attention was clearly on the reaction-time (RT) measures, subsequent analyses were confined to variables derived from these measures. In particular, absolute—RT(Dual)–RT(Single)—and relative—RT(Dual)–RT(Single)—indices of dual-task impairment were computed.

Correlation matrices for the relevant dependent variables in Studies 1 and 2 are presented in Tables 2 and 3, respectively. Values in parentheses along the diagonal are estimated reliabilities derived by applying the Spearman-Brown formula to the correlation between the values obtained in the two separate administrations of the task. All remaining correlations involving measures with more than one estimate are based on the average of the estimates from the two administrations of the task.

## Discussion

### *Age Effects*

The age correlations illustrated in Tables 2 and 3 indicate that age effects were relatively small on the various measures of anticipatory processing. One notable exception to this trend is the significantly positive correlation between age and replacement span in Study 1 (Table 1), suggesting that older typists commit to a stimulus character earlier than do young typists.

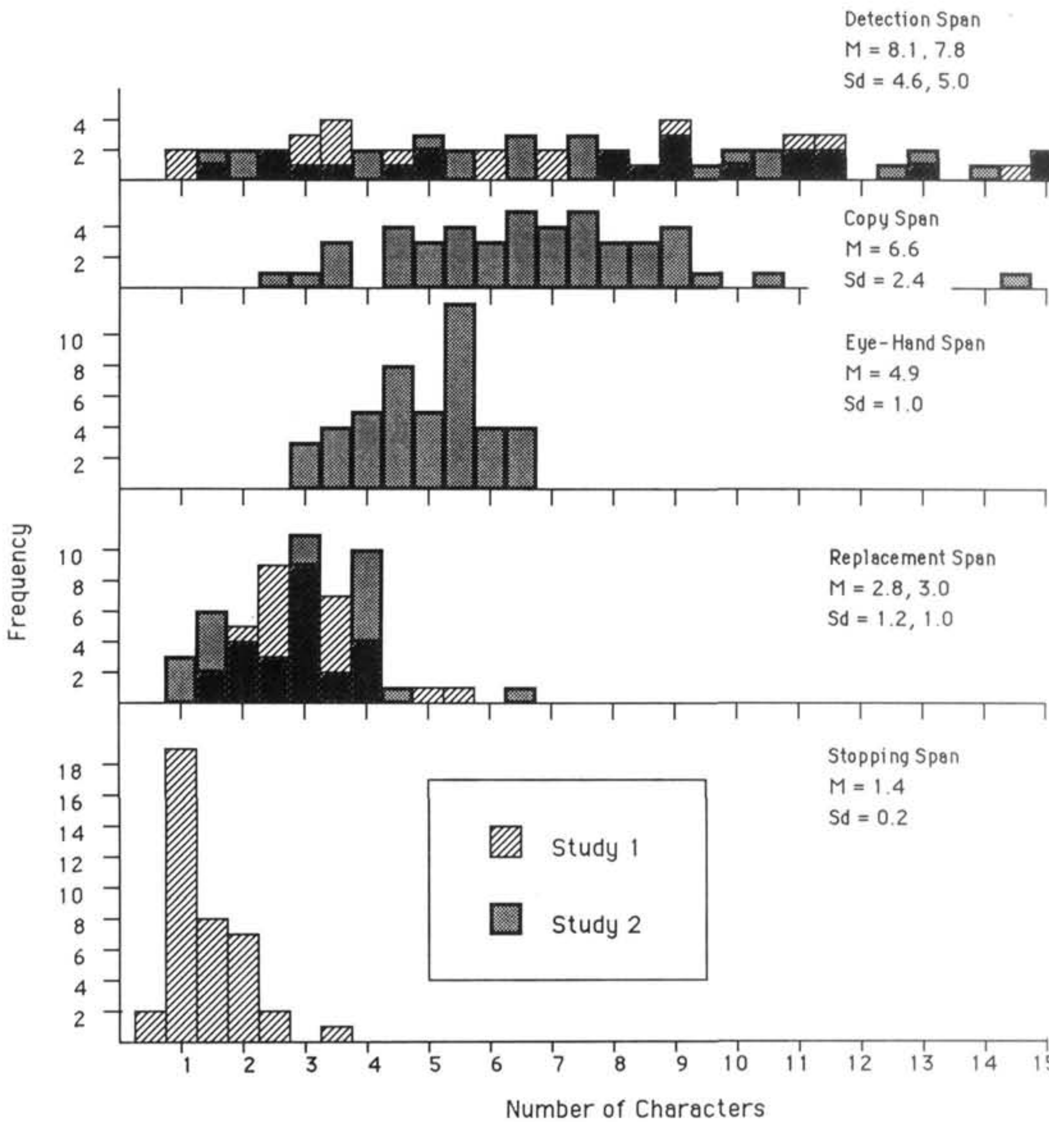


*Figure 1.* Distribution of subjects with each magnitude of span across the five span tasks in Studies 1 and 2.

Several factors might be responsible for the small age effects in the current studies relative to those found by Salthouse (1984), but unrepresentative sampling is apparently not one of them. The subjects in the present studies exhibited correlations between age and digit symbol score of −.55 and −.42, respectively, which are comparable to the values reported in several large-scale studies (e.g., see Salthouse, 1985b, for a review).

More plausible reasons for the smaller age effects are a restricted range of typing experience in Study 1 and underrepresentation of older ages in Study 2. That is, the typists in the Salthouse (1984) studies had maximums of 552 and 600 months of experience performing typing 10 hr per week or more, whereas the typists in the present Study 1 had a maximum of only 288 months. Furthermore, the correlation between age and this experience variable was above .5 in both of the studies in Salthouse (1984), but was only .13 in the present Study 1. If the compensatory effects associated with aging require extensive experience for their development, it is probably unrealistic to expect them to be evident in samples that have only moderate amounts of experience and in which the older typists don't have considerably more experience than the young typists.

A relatively small percentage of older typists may account for the attentuated age effects in Study 2 because the oldest typist was only 64 years of age, compared to 68 and 72 years in the Salthouse (1984) studies. Perhaps even more important is that only 10% of the subjects in the current Study 2 were 60 years of age or over, whereas 18% of the subjects in both of the previous studies were in this age range.

One intriguing exception to the generally small age effects are the negative correlations between age and the two variables reflecting amount of dual-task interference. Older typists expe-

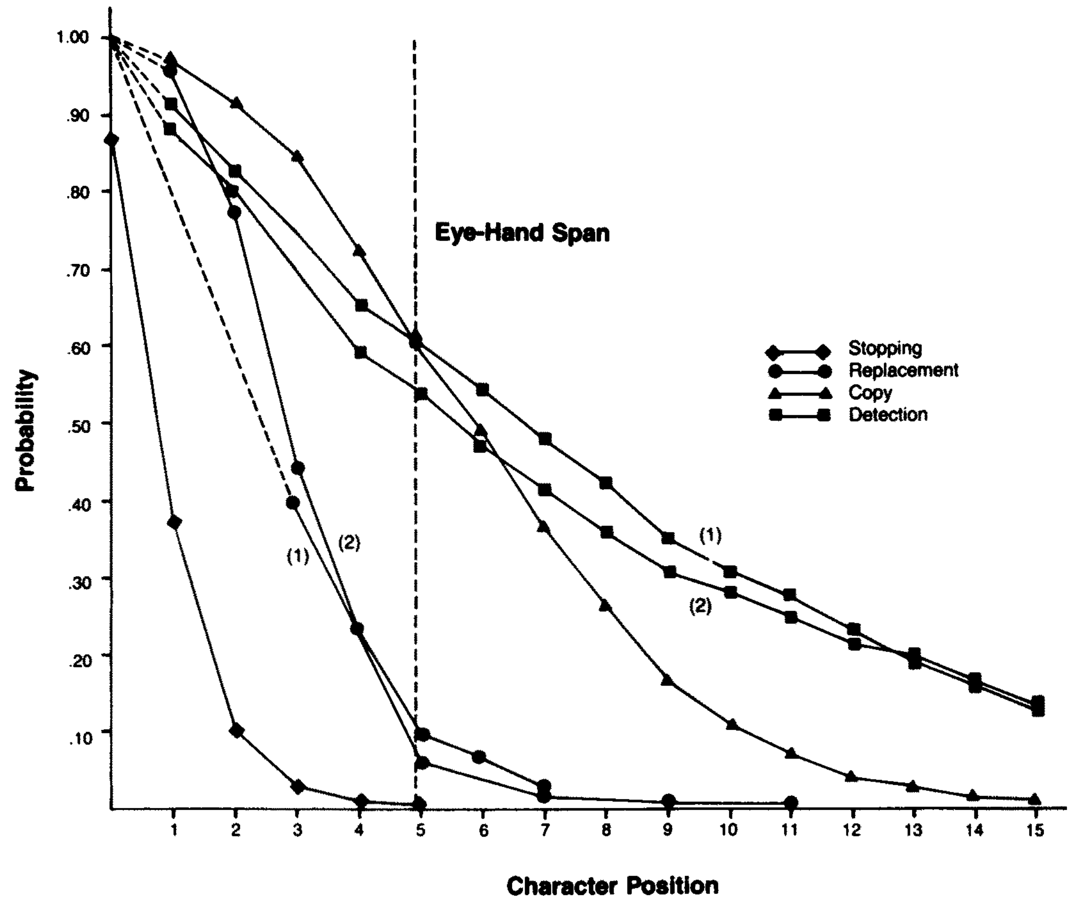


*Figure 2.* Probability functions across character positions for the different span tasks in Studies 1 and 2. (The dashed vertical line represents the mean eye–hand span across subjects.)

rienced more interference with a concurrent task while typing than did young typists, even though they were indistinguishable in overall level of typing proficiency when typing was performed alone. One interpretation of this result is that the older typists, relative to young typists, are using more of their available processing capacity performing the typing task and thus have less in reserve for the performance of additional simultaneous tasks. It therefore seems reasonable to infer that although the young and older typists perform at equivalent levels on the primary task, the older typists may be closer to their limits than are the young typists.

A similar finding that older adults experience greater absolute increments in reaction time when performing a concurrent task than do young adults has been reported by Salthouse and Somberg (1982) and Somberg and Salthouse (1982). The present results extend the earlier ones, however, by demonstrating that the phenomenon is evident in both absolute and relative measures of dual-task interference, and is apparent even when the subjects are very experienced in the primary activity.

## *Skill Effects*

Typing skill, as indexed by net words per minute, had moderately positive (and significant, $p < .05$) correlations with each

Table 2
*Correlation Matrices for Study 1*

| Measure | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1. Skill | (.98) | .01 | .57 | .15 | .47 | .46 |
| 2. Age | | — | .08 | −.33 | .16 | .42 |
| 3. Copy span | | | (.85) | .03 | .39 | .41 |
| 4. Detection span | | | | (.91) | .14 | −.12 |
| 5. Eye–hand span | | | | | (.54) | .38 |
| 6. Replacement span | | | | | | (.71) |

Table 3
*Correlation Matrices for Study 2*

| Measure | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1. Skill | (.98) | .07 | .07 | .80 | .56 | −.34 | −.38 |
| 2. Age | | — | −.07 | .16 | .13 | .53 | .35 |
| 3. Detection span | | | (.78) | −.15 | −.26 | .08 | .14 |
| 4. Replacement span | | | | (.84) | .71 | −.08 | −.11 |
| 5. Stopping span | | | | | (.83) | −.03 | −.13 |
| 6. Reaction-time difference | | | | | | — | .90 |
| 7. Reaction-time ratio | | | | | | | — |

of the span measures except detection span. Faster typists, therefore, had larger copy spans, eye–hand spans, replacement spans, and stopping spans than did slower typists. Positive correlations have been reported previously for each span measure except replacement span (e.g., Logan, 1983; Salthouse, 1984, 1985a), although in several cases the earlier correlations were not significantly different from zero. These results clearly suggest that an important concomitant of typing skill is greater anticipation at each of several processing components.

Skill was negatively correlated with both measures of dual-task interference, indicating that faster typists experienced less interference in reaction time when that task was performed concurrently with typing. This finding is consistent with earlier reports (e.g., Dvorak, Merrick, Dealey, & Ford, 1936; Shaffer, 1975) that highly skilled typists are able to perform other activities while maintaining competent typing, but it also extends those reports by demonstrating that this effect systematically increases with increased skill.

Although it was hypothesized that more skilled typists might have larger spans in part because of their greater reserve capacity, the correlations between the measures of dual-task interference and estimates of detection span, replacement span, and stopping span were uniformly low. Unfortunately, because the reaction-time tasks substituted for the copy span and eye–hand span tasks in Study 2, the relation between dual-task interference and copy span and eye–hand span could not be determined. However, the available results are not consistent with the hypothesis that skilled typists had larger spans simply because they had greater surplus capacity to devote to the special requirements of the span tasks, because the correlations between the index of surplus capacity and span magnitude were quite small.

## *Multiple Spans*

A major finding of Studies 1 and 2 is that measures of anticipatory processing thought to correspond to separate components of typing are of different magnitudes. These results are clearly consistent with the four-component model outlined earlier, and seem to necessitate a distinction among at least three phases of processing in any comprehensive theory of transcription typing. The correlational evidence was much more equivocal because although the reliabilities were generally moderately high, only the correlation between stopping span and replacement span in Study 2 was of comparable magnitude and these two spans were postulated to originate in different processing components. Possible reasons for the low correlations among measures thought to reflect the same processing component are mentioned in the following discussion of specific spans.

The magnitude of the detection span was quite variable across subjects, possibly because several different strategies could be used in this task. On the one hand, subjects could simply try to type normally and emit a detection response only when a target was accidentally encountered near the occurrence of one's current keystroke. On the other hand, the subject could periodically decide to interrupt his or her typing to scan for targets, thus detecting the target at very great distances and resulting in larger detection spans.

The moderately high reliability coefficient suggests that the subjects were consistent in their utilization of a given strategy across the two administrations of the task, but it is unclear whether the measures represent the same concept in different subjects. Moreover, to the extent that the detection span does not represent a single entity; it may be unrealistic to expect it to be related to typing skill or to other span measures.

Copy span averaged 6.6 characters in Study 1, which is considerably smaller than the value of 13.2 obtained by Salthouse (1985a) and the value of 40 reported by Rothkopf (1980). Variations in task demands and stimulus material are probably responsible for most of these differences. Rothkopf required subjects to look at the source text and then try to type as much as they could remember, thus emphasizing memory rather than naturalistic typing. Salthouse (1985a) used meaningful text as the stimulus material, and the larger spans in that study may be a consequence of the easier predictability from prior context compared to the current study in which unrelated words were used as the source text.

The copy span is interpreted as indicating that average typists have about 6 to 7 characters in a temporary input buffer. The contents of this buffer are assumed to be easily coded chunks from the source text, and thus would be expected to vary in size with the familiarity and redundancy of the material.

The eye–hand span in Study 1 averaged 4.9 characters, which is somewhat higher than the estimates of 3.4 to 4.0 reported in earlier studies (e.g., Salthouse, 1984, 1985a). Inspection of the distribution of spans revealed that, compared to the previous studies, the current study had fewer subjects with spans below 4.0 but a very similar maximum span. The fact that the current study used four-letter words as stimulus material, whereas the other studies all used meaningful text containing words of variable lengths, may contribute to this higher minimum, but the exact mechanism responsible is still unclear.

By definition, the eye–hand span refers to the number of characters necessary to ensure a normal rate of typing. Because the values from this indirect procedure are similar to those reported by Butsch (1932) in direct measurements of the focus point of the eyes relative to the character being typed, it seems reasonable to infer that the eye–hand span corresponds to important aspects of processing. According to the model proposed by Salthouse (1984, 1986), the eye–hand span originates in the parsing component as individual characters are isolated and then sent to the translation and execution components for further processing.

The replacement span estimates were very similar in Studies 1 and 2, despite much greater resolution with the procedure used in Study 2. The results indicate that average typists tend to commit to a particular character about three characters in advance of the keystroke for that character. If the stimulus is changed before this time, the change is detected and the second character is typed, but if the switch occurs later it is typically unnoticed and the initial character is typed. This pattern suggests that, on the average, subjects relinquish further monitoring of the source text about three characters in advance of the keystroke.

The final anticipation measure is the stopping span, which averaged about 1.8 characters. This value is consistent with those reported by Logan (1982) in several variants of the stopping span task, and is also of the same magnitude as error detection responses observed when subjects are required to indicate when they have made an error (e.g., Long, 1976; Rabbitt, 1978; Shaffer & Hardwick, 1969). These latter findings are relevant because error detection can be assumed to function like a stop signal, and the responses to that signal typically occur within one to two keystrokes. Also in this range are the estimates of the amount of prior context found to influence the variability of a given keystroke (Gentner, 1982, 1983; Salthouse, 1985a). All of these phenomena are postulated to reflect the contents of the execution buffer containing already translated movement specifications no longer under the control of the subject.

Notice that although both the replacement span and the stopping span are interpreted as indices of points of commitment on the part of the typist, they are postulated to differ in the types of commitment involved. The replacement span indicates that the subject is committed to typing a particular character *if a keystroke response is to be made,* whereas the stopping span represents the number of responses that the subject is *committed to making.* In terms of the model outlined earlier, the replacement span corresponds to the characters sent from the parsing component to the translation and execution components, whereas the stopping span corresponds to the number of translated response codes in the execution buffer.

This distinction between the two types of commitment is on rather tenuous grounds because although all of the subjects had larger replacement spans than stopping spans, the largest cross-task correlation in Tables 2 and 3 was between the stopping span and the replacement span, implying that they may involve the same process. In fact, Logan (personal communication, November 1985) suggested that the two spans may reflect the same type of commitment and yield different estimates primarily because the stimuli in the two tasks differ in saliency.

It therefore seemed desirable to conduct a supplemental study specifically focusing on possible differences and similarities between the stopping span and the replacement span in order to clarify this potentially important distinction between commitment to a character given that a keystroke is to be executed, and commitment to execute a keystroke. The approach used to investigate possible similarities and differences between the stopping span and replacement span tasks involved a hybrid task in which typists were instructed to stop typing whenever they detected a stimulus replacement. That is, as in the replacement task the typists were to type the most recent material that appeared on the display, but now whenever they noticed a character replacement they were to stop typing for several seconds before resuming their normal typing.

An additional task assessed the probability of detecting, and rapidly responding to, a stimulus replacement when no typing was required. The stimulus display consisted of right-to-left scrolling of the text as in the typing tasks, but the subject was instructed not to type and to press a key ('/') as rapidly as possible when a character substitution occurred in the display.

These new tasks, in addition to normal typing, the stopping span task, and the eye–hand span task, were administered to 10 typists ranging in age from 21 to 49 years and ranging in skill from 39.0 to 72.9 gross wpm.

Figure 3 portrays the results from this supplemental study in the same format as that used in Figure 2 to summarize the results of Studies 1 and 2. Comparison of the two figures reveals that the findings concerning the relative magnitudes of the stopping span, replacement span, and eye–hand span are replicated. Of particular interest is the finding that the functions for the replacement span and stopping span tasks are distinct even when the stopping response is triggered by the replacement stimulus. This suggests that although stimulus saliency may play a role in the stopping span task, it cannot account for all of the differences between the estimates derived from the stopping span and replacement span tasks.

Figure 3 also contains data corresponding to the probability of responding to (i.e., detecting) the character replacement in the replacement reaction time task and the stop-to-replace task. The function for the reaction-time task is rather noisy, perhaps because there was no constraint on eye position when the text scrolled without any typing, but it is still clear that detection probability was low when the replacement occurred near the left edge of the display. This trend is much more pronounced in the data from the stop-to-replace task, where the probability of detecting a stimulus change is greatest when it occurs three or four characters before the keystroke, but declines markedly as the replacement occurs earlier or later than this position.

These data on the probability of detecting the character replacement suggest that the stopping and replacement spans do not differ only in terms of the saliency of the stimulus because many of the replacement stimuli are not even detected. If the time to respond to the stimulus was the only factor responsible for replacement spans exceeding stopping spans, then one would expect the detection probabilities to be uniformly high, or at least to decline only at character positions greater than four. The results in Figure 3 indicate that this was not the case, and instead there was a systematic drop in probability of detecting a stimulus replacement as it occurred closer to the time of the keystroke for that character.

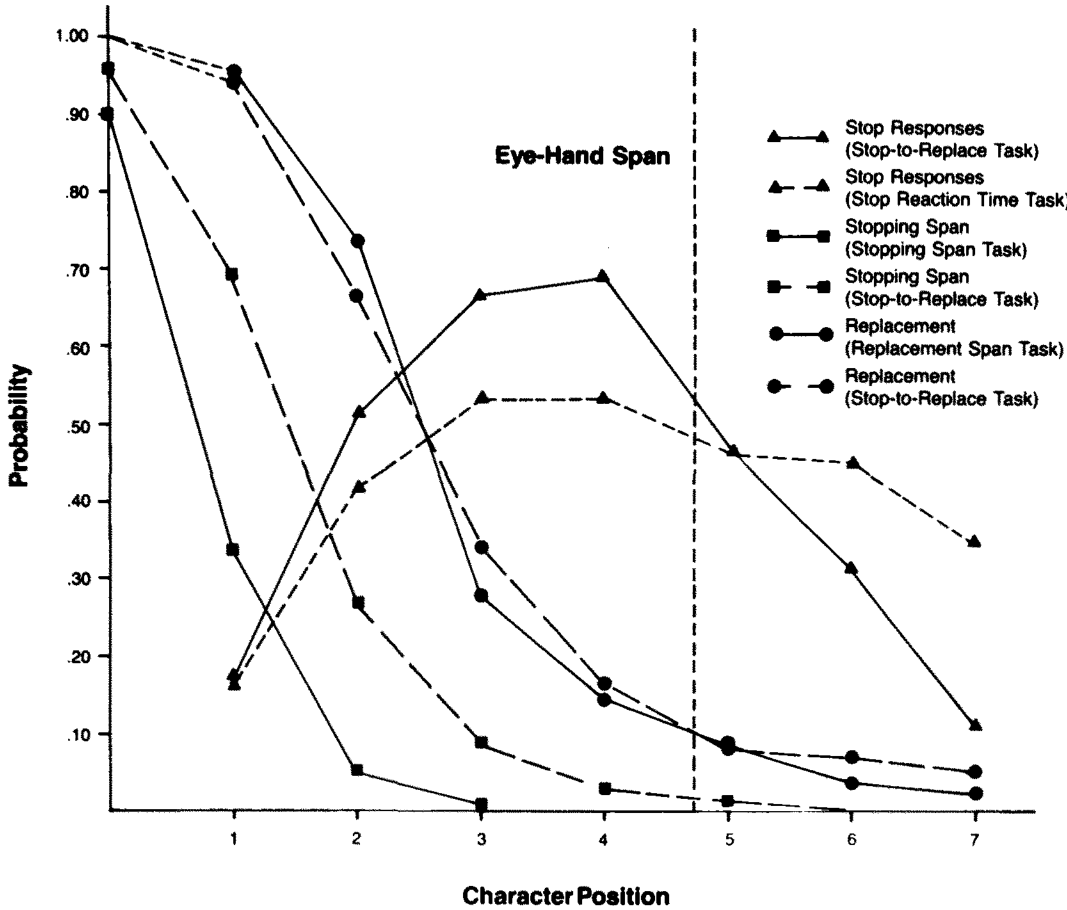


*Figure 3.* Probability functions across character positions for the experimental tasks in the supplemental study. (The dashed vertical line represents the mean eye–hand span across subjects.)

The present studies clearly demonstrate that multiple spans of anticipatory processing can be identified in transcription typing. Even when the same typists were examined with the same types of material, markedly different distributions of span magnitude were obtained from different procedures. There is always some risk that estimates of varying magnitude are merely artifacts of the different procedures that are necessary to assess amount of anticipation at different processing components, but this possibility is minimized in the current project by using two separate procedures to obtain estimates relevant to each hypothesized component. That is, input processing was investigated by the detection span and copy span procedures, parsing processing was assessed by the eye–hand span and replacement span procedures, and execution processing was examined with the stopping span procedure that was found to yield values comparable to those previously reported from analyses of error detection and sensitivity to constraining context.

Because the evidence for the different spans was obtained from the same typists, the spans necessarily correspond to different amounts of time during which preparatory processing is occurring. That is, the product of median interkey interval and span size in number of characters in Studies 1 and 2 averaged 1,430 ms for detection span, 1,132 ms for copy span, 868 ms for eye–hand span, 484 and 509 ms for the two estimates of the replacement span, and 224 ms for the stopping span.

These results are relevant to a hypothesis proposed by Butsch (1932) that the central nervous system appears to be organized such that processing begins approximately 1 s in advance of the required action. The present results indicate that this 1-s rule is at best very gross and at worse misleading because several distinct types of preparation can be distinguished, each apparently having its own unique temporal constants.

What do the current spans measure? Perhaps the safest conclusion is that they reflect the time course of different types of processing relevant to a specific keystroke. Processing concerned with the initial input of the material appears to occur about six to seven characters before the keystroke, whereas something analogous to the parsing or isolation of characters occurs between three to four characters in advance of the keystroke. And finally, specific keystrokes are committed about one to two characters before the actual keystroke.

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