THE EFFECTS ON ATTENTIONAL FOCUS ON AUTOMATED SKILL PERFORMANCE

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THE EFFECTS OF ATTENTIONAL FOCUS ON AUTOMATED SKILL PERFORMANCE

An Abstract

Presented to

the Graduate Council of

Austin Peay State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

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by

Elizabeth H. McDugald

March, 1984

ABSTRACT

According to attentional theory, certain activities such as walking, typing, or driving a car become "automated" with sufficient practice and no longer require attention for efficient execution. It has been suggested that attention to a motor aspect of such activities may even prove disruptive once the activity has become automated. This experiment was designed to test this idea by requiring typists to focus attention on various aspects of typing. After the initial typing of a test paragraph, subjects in three groups were asked to re-type the same paragraph with an added task. One group was asked to count the number of times they used the third finger of the left hand; one group was to count the number of times they typed the letters "p," "k," and "q;" and a third group was to count the number of times they typed the word "and." A fourth group served as a control group and was asked only to re-type the paragraph with no added task. Analysis of results indicated that subjects asked to count finger movements took significantly more time to re-type the paragraph than the other groups. The average time increase for the finger group was 47.33 seconds as compared to 8.67 seconds for the letter group, -1.47 seconds for the "and" group, and -2.73 seconds for the control group. There was no significant change in the number of errors made by any of the four groups. These results seem to suggest

that attention may have a disruptive influence when focused on a motor aspect of an automated activity.

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---

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March, 1984

To the Graduate Council:

I am submitting herewith a Thesis written by Elizabeth H. McDugald entitled "The Effects of Attentional Focus on Automated Skill Performance." I recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Arts, with a major in Psychology.

Charles R. Grah

Major Professor

We have read this thesis and recommend its acceptance:

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INTRODUCTION

One of the most fascinating aspects of cognitive functioning is the role of the process called attention. There are several apparently paradoxical ways in which attention operates. It may be involuntarily invoked by the intrusion of a novel stimulus from the environment, or it may be deliberately focused on an external event or object by the internal mental processes of the individual. It may even be focused on the internal mental processes themselves. It is essential to the learning process, yet the apparent goal of skill learning is to minimize the need for attention, perhaps to eliminate it altogether so that attention can be utilized in the performance of other concurrent tasks.

Even a child understands what is meant by the admonition to "pay attention." Empirically, it seems to be simply a focusing of mental resources on a particular object or idea. This universal subjective experience is what William James was referring to back in 1890 when he wrote that "Every one knows what attention is." He went on to define it as "the taking possession of the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought" (p. 403). In discussing the question of how many different things can be attended to at one time, he stated that "the answer is, <u>not easily more than one</u>, unless the processes are very habitual" (p. 409).

Anderson (1980) offers some metaphorical models which may be helpful in conceptualizing the process of attention. He states that it may be thought of as an energy source with a fixed amount of current to be allocated among various tasks; as a work-space with a limited amount of room in which to function; or as an animate entity operated by "a small set of agents, often called 'demons'" (p. 26). The number of tasks that can be performed at one time is limited by the number of "demons" available. These metaphorical models are roughly analagous to the "single channel" model of Broadbent (1958), the "capacity" model of Kahneman (1973), and the "multiple resources" model of Navon and Gopher (1979), all of which are briefly reviewed below.

Broadbent (1958) speculated that all information is handled by one channel with a limited capacity. His theory was based in part on extensive dichotic listening experiments by Cherry (1953) who demonstrated that when two simultaneous messages were presented by earphones to subjects who were asked to "shadow" only one message by repeating it back, most information from the second message was excluded from awareness. Subjects were able to distinguish between a male or female voice in the unattended message, but were not able to report the meaning of the message. Broadbent (1958) uses the analogy of "a radio receiver designed to eliminate impulse interference" to account for the exclusion of unattended information, and refers to this concept as "the Filter Theory, since it supposes a filter at the entrance to the nervous system which will pass some classes of stimuli but not others" (pp. 41-43). This theory has since been modified as a result of experiments by such researchers as Triesman (1960) who demonstrated that subjects in dichotic listening tasks would sometimes switch attention from one ear to the other in order to follow a meaningful message. McKay (1973) showed in his research that words presented to the unattended ear during a shadowing task could influence the meaning of the message being shadowed. These results indicate that information on the unattended channel is actually processed at a semantic level rather than being filtered out at an earlier level as originally suggested by Broadbent.

Kahneman (1973) proposes a capacity model of attention which depends on an allocation policy to distribute the limited capacity to meet the demands of the various body structures. He suggests that this capacity may be flexible to the extent that it may increase or decrease in response to the arousal level of the organism or the demands of the activity. In this respect it differs from the rigid capacity model suggested by Anderson's metaphor. Kahneman uses the terms "effort," "capacity," or "attention" to describe the "nonspecific input" which is evaluated and allocated to specific structures for activation.

Navon and Gopher (1979) refer to attentional capacity as "resources," a term they credit to Norman and Bobrow (1975). Rather than a single pool of resources, or a single processing channel, they envision a system incorporating "a number of different mechanisms, each having its own capacity." Under this concept, "tasks interfere with each other to the extent that their demand compositions are similar so that they have to compete for resources" (p. 238). Rather than a flexible capacity, as suggested by Kahneman, they propose that an added task may not increase capacity but may instead have properties which enable the secondary task to utilize different resources which are not engaged in the primary task. This concept may explain some of the inconsistencies found in many dual task experiments which indicate that there is less interference between tasks when the tasks are dissimilar in nature. This idea was investigated by McLeod (1977) who performed an experiment which required subjects to respond either vocally or manually to a tone identification task while simultaneously engaged in a manual tracking task. Although the group which responded manually were instructed to use the hand not engaged in the tracking task to respond to the tone, the performance of these subjects was significantly worse than that of the subjects who responded vocally. McLeod believes that these results lend support to the multiple resources theory. However, Posner (1982) finds no incompatibility between the multiple resources and the single channel views. Instead, he sees a combination of the two with much processing being accomplished by different isolated systems but with coordination being "achieved through a limited capacity system that might be identified with conscious awareness" (p. 171). Thus a bottleneck effect is observed when a number of incoming signals require the use of some common structure at a higher level in the hierarchy.

An interesting aspect of attention which none of these theories address is how some tasks can become automatic with practice. The term "automaticity" refers in the broadest sense to any cognitive, verbal or motor skill which has been learned and practiced "to the extent that it is coordinated without attentional control" (Logan, p. 189). By this definition, speaking, walking, and typing are all considered automated activities.

The development of automaticity has been studied in the context of motor skill learning by Fitts and Posner (1967). The authors draw an analogy between the organization of a skilled performance and a computer program consisting of fixed sequences, or "subroutines," which are repeated over and over again under the control of the overall plan, or "executive program." These fixed units of movement are automatic and may be used in many different skills. An example might be the extension and flexion of the fingers, a motor action which becomes incorporated in the performance of innumerable daily activities ranging from grasping an object to typing or playing the piano.

Fitts and Posner identify three stages of skill learning.

First is the "early or cognitive" stage when it is necessary to attend to visual and kinesthetic cues, and to direct attention to the selection of appropriate subroutines. One example given is the person learning a new dance step. At this early stage, he or she must watch the feet and notice how they are placed. Instructions and demonstrations are effective at this stage, and "can be considered as a first step in the development of an executive program" (p. 12). Subroutines which have already been learned such as stepping forward or back are incorporated into a new pattern. During this phase, errors are frequent and "behavior is truly a patch-work of old habits ready to be put together in new patterns" (p. 12).

Next comes the "intermediate or associative" stage when the already learned subroutines become associated with the new patterns through practice. During this phase, errors such as "grossly inappropriate subroutines, wrong sequences of acts, and responses to wrong cues" are gradually eliminated (p. 12). Speed of performance also increases during this stage. An experiment by Fitts and Switzer (cited in Fitts, 1964) demonstrates how the time required to produce an unfamil-iar vocal response to a picture stimulus is reduced as new associations are formed by practice. In this experiment, subjects were asked to respond vocally to pictures of familiar objects with a letter of the alphabet. In one condition, the letter response was the first letter of the name of the object (e.g. "H" for house). In the second condition, the same letters were assigned randomly with the restriction that the correct letter response was not the first letter of the object pictured. After pre-training to the point where subjects achieved two correct trials, reaction times were recorded over five 30 minute test sessions. Results showed that while mean reaction times for those groups required to give the unfamiliar letter response were consistently longer than for those who gave the familiar letter response, the mean times for both groups decreased steadily with practice over the five sessions, and initial improvement was faster for those learning the unfamiliar letter responses.

During the "final or autonomous" stage, the activity becomes more automated and less subject to direct cognitive control. This is the stage when it is possible to walk, for example, and carry on a conversation at the same time. The activity of walking is under the control of the executive program and does not interfere with the activity of talking (Fitts and Posner, 1967). The authors cite an experiment by Bahrick, Noble and Fitts (1954) involving two groups of subjects who were required to push keys in response to lights, some of which appeared at regular intervals, others randomly. The concurrent task was to perform orally presented arithmetic problems. The results showed that after considerable practice in the predictable response condition, subjects were able to perform the secondary arithmetical task efficiently and with little interference to the primary task of key pressing. These results support the view that an autonomous stage can be achieved through continued practice, that the primary skill requires little conscious processing at this stage, and that it "can be carried on while new learning is in progress" (pp. 14-15). It is interesting to note, however, that the subjects responding to the light presented at random intervals were less efficient and experienced more interference with the secondary task than subjects responding to the light presented at regular intervals. This seems to indicate that predictability may be an important element in the development of automaticity. Also, the point is made by the authors that performance is not static once the autonomous stage has been achieved. It may continue to improve in terms of both speed and proficiency with continued practice, although at a slower rate than during the associative stage.

An important aspect of the learning process described above is the role played by feedback. Fitts and Posner (1967) define feedback as follows:

> Since skilled behavior requires sequences of activity, both sensory information and response movements are continually involved. Moreover, much relevant information is in the form of stimuli arising from previous responses or environmental consequences of those responses. These sources of information are collectively called <u>feedback</u>. The only response sequences free from feedback

> effects are those which are so short that there is insufficient time for feedback information to be processed and modify the response. Feedback is highly important whenever a skilled performance lasts for more than a second. (p. 2)

According to Schmidt (1980), the need for monitoring skilled performance by means of feedback tends to decrease as the level of skill increases. Such monitoring requires attention, and when attention is directed elsewhere, the execution of an activity which has become fully automated may be turned over to a centrally stored program, or blueprint, which automatically directs the activity until correction or adjustment is required, at which time the feedback mode will be called upon. In other words, either method may be used at will, depending upon the circumstances. Schmidt sees this flexibility as an example of the redundancy often observed in biological functions.

One phenomenon which has been noted by several researchers in the field but which seems never to have been systematically investigated is the disruptive effect produced by consciously focusing attention on a specific motor function within an automated skill. Anyone who has engaged in a sport such as golf or tennis may have experienced this disruption when trying to improve performance by analyzing some particular aspect of his or her swing. Attention may be focused on the performance of one specific subroutine, such as wrist action, and the chances are good that the overall swing will deteriorate until the desired change is incorporated or the original pattern is reinstated, allowing the "executive program" to re-establish itself. Fitts and Posner (1967) note that "If the attention of a golfer is called to his muscle movements before an important putt, he may find it unusually difficult to attain his natural swing" (p. 15).

Schmidt (1980), in discussing the role of feedback in the performance of automated skills, notes that while feedback is obviously necessary in such activities as driving a car, it may in some instances prove disruptive. He writes that "a common example is asking a pianist to think about what a particular finger is doing in a complex piece, and disruption of skill is usually found" (p. 126). It is not clear whether he means that the feedback itself is disruptive, or whether he means that being forced to return to the feedback mode of performing is disruptive. He goes on to say that evidence on this and other questions of a similar nature is limited and "should provide interesting work for the future."

The purpose of the following experiment is to determine whether a task involving the focusing of attention on a component motor function within an automated skill disrupts performance more severely than focusing attention on a similar cognitive task which does not involve any aspect of the motor function. The skill chosen to test this proposition was typing. The acquisition of typing skill is a complex process involving a "hierarchy of stroking habits" (West, 1969, p. 73).

Three overlapping stages of learning are identified by West: (1) a "pre-letter stage" which requires vocalization of each letter as an intermediary stimulus between the visual perception of the letter and the actual stroking of the letter; (2) a "letter-level stage" when vocalization is no longer necessary but each letter serves as a stimulus and muscular sensation begins to provide an index of correctness; (3) a "chained-response stage" when frequently occurring sequences of letters are typed as sequences rather than as separate letters, and kinesthetic sensations serve both as stimuli for succeeding strokes and as feedback for correctness after a stroke. According to West, response chains usually consist of two or three letter sequences, not necessarily syllables. Only very highly skilled typists, those who are capable of speeds above 80 words per minute, have the ability to type at the word level, and even then there is "an interweaving of chained with single-stroke responses" (p. 73-74).

In order to induce subjects to focus attention on a particular motor function of typing, subjects in one group (Group A) were asked to count the number of times they used a certain finger (in this case, the third finger of the left hand) when typing a test paragraph. It was predicted that this would prove most disruptive for skilled typists since it would not only focus attention on the motor function of striking a particular key (which presumably has become automatic), but it would also require them to type at the "letter-level stage" rather than the "chained-response stage."

In order to control for the possibility that subjects in Group A might utilize a strategy of counting the letters typed by a particular finger instead of concentrating on the finger movements, a second group of subjects (Group B) was asked to count the number of times they typed three letters (in this case, "p," "q," and "k") as opposed to counting finger movements. It was predicted that subjects in Group B would show less interference than those in Group A because even though they would also be required to type at the "letter-level stage," they would not be required to focus attention on a specific motor function. However, if subjects in Group A were in fact using this strategy, then there should be no significant difference in the performance of the two groups.

Since it has been demonstrated by many researchers (e.g. West, 1969; Logan, 1982) that typing responses of skilled typists often consist of frequently used words of two or three letters, a third group (Group C) was asked to count the number of times they typed the word "and" in the test paragraph. It was predicted that this task would show less interference than the other two since it would not disrupt the "chained-response" level of typing and would not focus attention on a motor function.

All three of the groups were required to type the test paragraph twice, first at their normal rate and secondly with the added task as described above. A fourth group (Group D) was added to control for any significant practice effect resulting from having typed the paragraph once. This group was asked only to re-type the same paragraph with no added task.

Chapter 2

METHOD

Subjects and Design

The subjects were volunteers from the professional staff at Austin Peay State University, from student workers assigned to university offices as typists, and from advanced typing classes in the Continuing Education program at APSU. The criterion for skill level was that they must be able to type the test paragraph consisting of approximately 200 standard words at a minimum rate of 40 words per minute (wpm). Skill levels ranged from a maximum speed of 101 wpm to a minimum of 40 wpm, with a mean rate of 64 wpm. Errors ranged from 0 to 35 for the entire paragraph, with a mean rate of 9.4 errors per minute (epm). The 60 subjects were randomly assigned to the four experimental groups, with the restriction that 15 subjects be assigned to each group. Subjects were tested in their own offices on the typewriters that they normally used. Arrangements were made to prevent interruptions during testing. In the case of the eight advanced typing students, a room was provided with a typewriter of the same make and model as those used in class.

Materials

Three paragraphs were chosen for use in the testing, all approximately 200 standard words in length and all in narrative form. The third paragraph (test paragraph) was devised to contain exactly the same number of combined occurrences (18) of the letters "s," "w," and "x" (the letters stroked by the third finger of the left hand); the letters "p," "q," and "k;" and the word "and." The three paragraphs are presented in the Appendix.

Procedure

The first two paragraphs were administered, one at a time, to each subject individually as a warm-up exercise. Each performance was timed and scored in order to allow the subject to become accustomed to the test conditions. Each was then asked to type the third (test) paragraph all the way to the end as quickly and accurately as possible and to indicate immediately when he or she had finished. Each paragraph was presented only when the subject was set up and ready to start so that no preview of the material was possible. Timing started with the word "Go" and ended with the subject's indication that he or she had finished the paragraph. After completion of the third (test) paragraph, each subject was instructed to type the same paragraph again, but with an added task as described below:

Subjects in Group A were instructed to pay attention to, and keep a mental count of, the number of times they used the third finger of the left hand. The correct finger was demonstrated to be sure they understood. They were asked to report the count on completion of the exercise, and this reported count was recorded along with the time and number of errors.

Subjects in Group B were instructed to pay attention to and keep a mental count of the number of times they typed the letters "p," "q," and "k." It was explained that they were not to count each letter group separately, but only to report a total number for all three. This count also was recorded along with time and errors.

Subjects in Group C were instructed to pay attention to and keep a mental count of the number of times they typed the word "and." This reported count was recorded along with time and errors. In all cases cited above, the actual number of occurrences for each condition was 18.

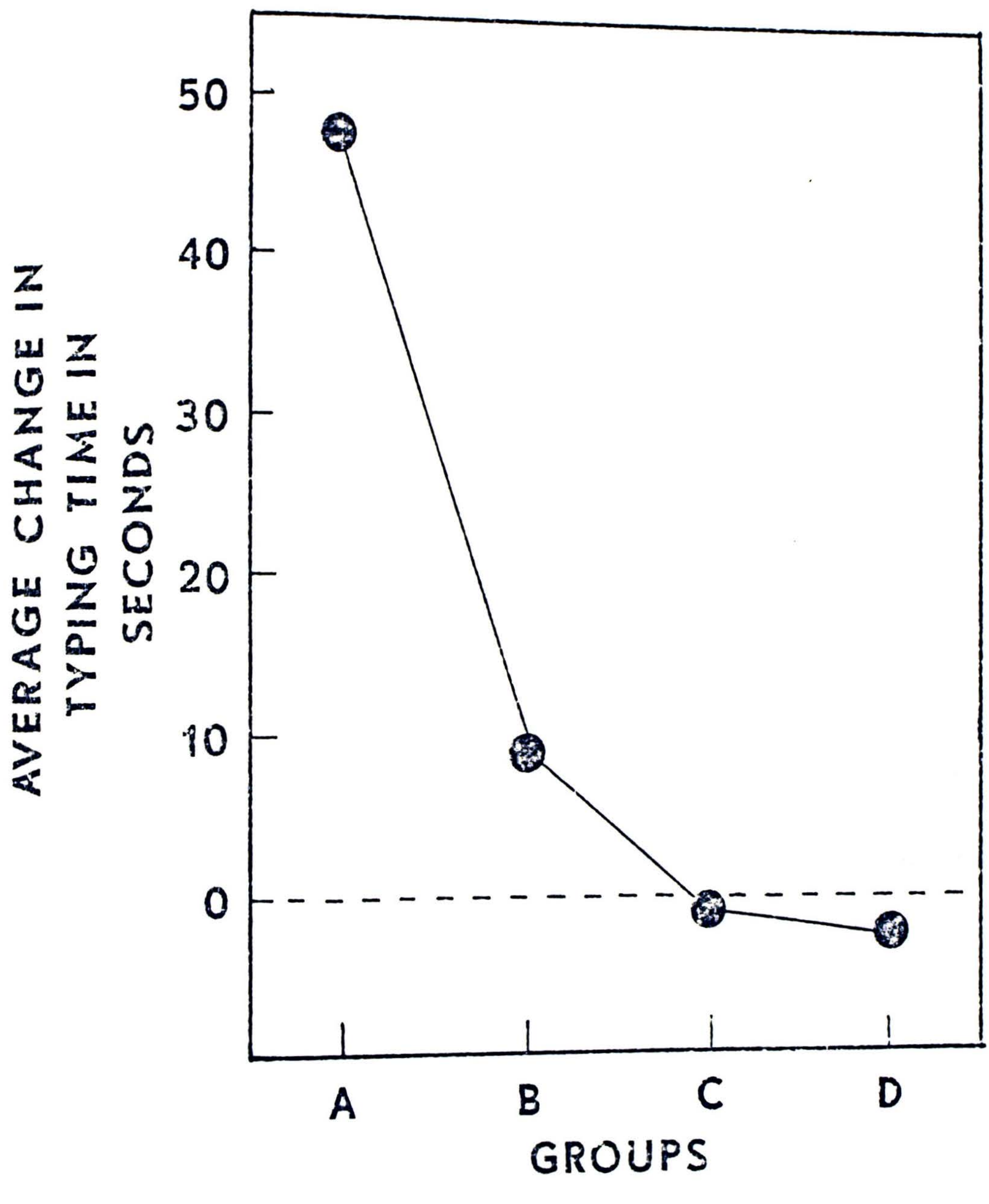
Subjects in Group D were asked only to re-type the test paragraph with no added task, and time and errors were recorded.

Chapter 3

RESULTS

For each subject, the time (in seconds) required for the first typing of the test paragraph was subtracted from the time required for the second typing. An analysis of variance was performed on these time differences for all four groups. The number of errors on the first typing was subtracted from the number of errors on the second typing and an analysis of variance performed on these differences. The same procedure was used for the accuracy of the reported count, except in this case only three groups were involved (Group D was not asked for an estimate) and the figures used were obtained by determining the number by which each reported count was over- or under-estimated.

The only significant results were obtained by the analysis of variance of the time differences, $\underline{F}(3,56) = 18.53$, $\underline{p} < .001$. A graph of the mean group time differences (Figure 1) shows an average increase in time for Group A of 47.33 seconds. Group B ($\overline{x} = 8.67$ sec.), Group C ($\overline{x} = -1.47$ sec.), and Group D ($\overline{x} = -2.73$ sec.) show no significant change. Furthermore, a Newman Keuls analysis identifies Group A as the group which accounted for the significant F ratio. Analysis of the error differences and the estimate differences for all four groups revealed no significance in either of these variables.


AVERAGE CHANGE IN TYPING TIME IN SECONDS
0
10
20
30
40
50
A
B
C
D
GROUPS

Chapter 4

DISCUSSION

These results confirm the earlier prediction that Group A would experience more interference with performance than the other groups and that attention may indeed have a disruptive effect when focused on some aspect of the motor function of an automated activity. They also indicate that in this case speed is the element most severely affected. Accuracy, as measured by the error rate and the correctness of the mental count, does not appear to be influenced. It may be that the slower pace of the subjects in Group A offset any tendency toward an increased error rate, either in typing or in keeping a mental count.

Since there was no significant difference in the performance of Group B (letter group), Group C ("and" group), or Group D (control group), then it must be concluded that the significant decrement exhibited by Group A (finger group) cannot be explained by the difficulty of paying attention to or counting certain occurrences. The only factor which might be responsible for the difference appears to be the requirement that attention be directed to a motor aspect of the automated skill.

A possible interpretation of the results of this experiment may lie in the explanation offered by Schmidt (1980) in his comment regarding the disruptive effects of feedback on the piano player. In the case of the typists, it is obvious that feedback in itself could not be the disruptive factor since any kinesthetic feedback received from striking the key with the designated finger would presumably indicate a correct motor response and would therefore not require a delay for correction or adjustment. However, it is possible that attention to the action of a specific finger may cause a momentary or sporadic regression to the early cognitive stage as described by Fitts and Posner (1967), when close attention to kinesthetic feedback is a necessary aspect of the learning process. In these circumstances, it might be the anticipation of, and attention to, feedback which causes disruption. Since being forced to type at the letter-level stage did not significantly affect the speed of the subjects in Group B, then it may be deduced that this momentary regression, if it occurs, must be to the earliest stage of the learning process.

If regression is responsible for the significant time difference shown by the finger group, it would seem reasonable to assume that the most highly skilled typists would be more severely affected than those who were still operating at an intermediate level. There were not enough subjects in this study who were capable of speeds of 80 wpm or above to draw any conclusions on this score. Another problem involved in attempting to analyze the performance of the expert typists is the strategy, which may have been employed by some, of transferring attention from the finger to the counting of the three letters, "s," "w," and "x," that are typed with that finger. This strategy, which we sought to control for with the letter group, is one which is likely to be employed only by the most expert typists. However, most of the subjects did not use this strategy or the results would have been quite different.

It was also predicted that subjects in Group C ("and" group) would experience less interference than subjects in Group B (letter group) since those in Group B would be required to type at the letter-level instead of the chained-response level. Although there was no significant difference between the performance of these groups, there does appear to be a slight trend in the predicted direction. It may be that the average subject in this study was not sufficiently skilled to be significantly affected by the necessity of typing at the letter-level. As noted earlier, West (1969) claims that large-scale chaining appears only at speeds above 80 wpm. He further states that there is usually only "modest" use of chaining at 60 wpm, and at lower speeds (i.e. 40-55 wpm) letter-by-letter typing is the norm. Since the average speed of the typists in this experiment was 64 wpm, it seems likely that the disadvantage of being forced to type at the letter-level would be minimal for most of the subjects. It might prove interesting to conduct the same experiment with a population of highly skilled typists (i.e. 80 wpm and up) since they would presumably be accustomed to typing in the chained-response mode. Again, there were not enough subjects in this category in each group to draw any conclusions on this score.

From the standpoint of the general theoretical models presented earlier in this paper, the significant results of this experiment might be interpreted as lending support to the multiple resources theory as opposed to the single channel theory. Although Posner (1982) sees no incompatibility between the single channel and the multiple resources theories, it is difficult to see how his interpretation of single channel theory can account for these results. He sees a bottleneck effect as the result of an excessive demand for coordination at some level of processing, but there is no reason to suspect that coordination would be more difficult if it involved two similar functions, or two aspects of one function, than if it involved totally dissimilar functions. If coordination is accomplished, as he suggests, at the level he identifies with conscious awareness, then it should be just as difficult to allocate attention to one activity as another while performing an automated skill. Navon and Gopher (1979), in discussing their conceptual framework for the idea of multiple resources, state that this approach accounts for "findings that indicate structure-specific interference that neither central capacity models nor structural models could adequately explain" (p. 247).

It should be pointed out that counting letters or words may simply be more compatible with certain highly practiced aspects of typing, such as letter or word recognition, than is the counting of finger movements. In any event, the answers to this and other questions that have been raised must await the results of further research.

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APPENDIX

Paragraph 2

When I was about seven years old, I found a small hole, barely an inch in diameter, in the bank behind our family's house. With a trowel, I excavated for hours, following the hole back into the bank with sweaty, mud-splattered determination through pale roots and the thick loamy soil. The hidden treasure was a vaguely startled salamander, marbled black and purple. Held in my hand, the salamander, a good eight inches long, emitted a low-pitched rattle. It was an unpleasant sound, and I dropped the creature. Afraid of what I had unearthed, I returned to the house and took a bath, soaking off the dirt as I looked through my family's book on reptiles. I had found a perfectly harmless Pacific Giant salamander, though it seemed mine was larger than the six inches it was said to reach. When I returned, the salamander had disappeared. My mother asked what I had been doing, and I said "Nothing."

Test Paragraph

Tom and Debbie turned slowly and contentedly in the direction of the hill. The moon coming up behind them looked round and benevolent, bright and gaudy like the globe of the lonely light in the little village they lived in. The silence of the trees outlined by the moonlight and the quiescence of the night breeze told of nature's hope and belief that winter no longer exerted the fierce power and potency of a former time. It was the time on the hill for the bold and primitive land to hold its breath before the thrill and rejoicing of the coming event. For much of the night, Tom and Debbie lingered and talked, climbing up and down on hill and valley in the burgeoning springtime. Tom and Debbie fell quiet and pensive as they watched the moon falling behind the rim of the looming ridge. The night felt soft and protective, and conveyed the feeling of coming upon a group of happy children tumbling joyfully on the green glen and the rolling hill.