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Chapter Eight

Age, Experience, and Compensation

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INTRODUCTION

An intriguing discrepancy exists between the competencies of older adults, assumed on the basis of everyday observations, on the one hand, and their competencies inferred from laboratory results, on the other. The laboratory results tend to portray older adults as distinctly inferior to young adults on a number of presumably basic cognitive abilities, and yet we are all aware of competent, and even remarkable, accomplishments of people well into their 60s, 70s, and beyond. One is thus faced with the question of how to account for this apparent discrepancy between the rather pessimistic results of the laboratory and the more encouraging observations of daily life.

One possible interpretation is that observations in daily life are unsystematic or biased because the activities are typically self-selected, and not representative of the entire population of potential tasks. That is, people probably tend to engage in activities in which they are reasonably competent, and try to avoid as much as possible those tasks which have proven difficult or stressful in the past. It is not clear whether the activities of daily living are inherently less difficult or complex than the tasks performed in the laboratory, but the fact that individuals are free (at least within broad limits) to choose their daily activities introduces the possibility of a self-selection bias which could drastically distort the meaning of one's observations.

A second hypothesis for the discrepancy between age trends in the laboratory and those inferred from observations of daily living is that the laboratory situation is artificial, and thus may be characterized by conditions of low motivation, high anxiety, or generally

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allocation of attention. Because these detrimental factors are presumably absent, or at least of considerably smaller significance, in the situations one typically encounters in the natural environment, the laboratory results may provide an unrealistic portrayal of the true capacities of older adults.

A third interpretation of the lab-life discrepancy is that laboratory tasks typically emphasize the processes of cognition while daily activities tend to reflect the prior or current products of those processes. This process-product distinction is similar to the fluid-crystallized dichotomy introduced by Horn and Cattell (1966), and the mechanics-pragmatics contrast recently proposed by Baltes, Dittmann-Kohli, and Dixon (1984). The fundamental idea in each of these conceptualizations is that there are qualitatively different types of cognition, with one exhibiting greater age sensitivity than the other. Divergent age trends in laboratory and real-life situations might be produced if the sample of abilities studied in the laboratory represents a different distribution of the two types of cognition from that involved in the activities of daily life.

A fourth hypothesis, and the one of greatest interest in the present context, is that the activities of daily living are highly practiced while tasks in the laboratory are typically quite unfamiliar. Because older adults have probably had much more experience performing activities of everyday living than young adults, if for no other reason than that they have lived 30 to 50 years longer, they can be considered to be experts in the domain of their own particular patterns of activity. It is thus conceivable that contrasts in the laboratory involve near-novice levels of performance, while those in the activities of everyday life consist of older adult experts being compared with young adult novices. This experience hypothesis is the focus of the remainder of this chapter.

A key question from the perspective of the experience hypothesis is exactly how greater experience might lead to a reduction in the magnitude of age differences in performance. Two distinct strategies have been pursued to investigate this question. One involves the direct manipulation of experience by means of the administration of training or practice in groups of young and old adults. The other strategy consists of indirectly assessing the effects of experience through an examination of detailed aspects of performance in adults of different ages who achieve the same overall level of proficiency with varying amounts of experience. Both studies involve perceptual-motor activities—an ability domain with three advantages for the purpose of this chapter. First, perceptual-motor tasks typically yield simple and objective measures of performance, often in the intrinsically meaningful scale of real time. Second, because this domain has been extensively researched, it has a number of reasonably well documented process models

And third, age-related declines in perceptual-motor tasks are often among the most pronounced of any behavioral variables, thereby providing a very strong test of the potential contribution of experience in modifying the effects of aging.

EXPERIMENTAL MANIPULATION OF EXPERIENCE

The basic goal with the strategy of experimentally manipulating experience is to administer enough practice on the relevant tasks to allow the members of each age group to achieve a relatively asymptotic level of performance. Contrasts of the initial and asymptotic levels of performance could reveal that the age differences remain stable, that they increase, or that they decrease. Of course, in all cases it is important to be sensitive to artifacts of measurement such as unreliable measures early in practice or ceiling effects late in practice which might spuriously produce, or obscure, interactions of age and experience (see Salthouse, 1985).

An outcome in which age differences are reduced with practice is the most intriguing in the current context because it is consistent with the view that practice-related factors contribute to the existence of the age differences observed in the laboratory. The critical issue, however, is how such a convergent Age × Experience interaction is to be explained.

One interpretation can be termed *remediation* in that the age differences are presumed to be reduced because experience leads to the older adults "remedying" their deficit. Remediation thus implies that practice has successfully altered the critical mechanism responsible for the initial age differences in a more optimal direction in the poorer-performing older adult group. What is sometimes known as the disuse theory of cognitive aging would be supported by a remediation interpretation because this perspective postulates that a lack of recent practice on the part of older adults is responsible for many of the age differences observed in cognitive tasks.

A second interpretation can be designated *accommodation,* since in this case the critical mechanism is not directly affected by experience but instead its consequences are minimized by a shift in the manner of carrying out the relevant tasks. Accommodation is unlikely to be a major factor in simple tasks, but in more complex situations it may be manifested as a shift in one's pattern of activities or mode of performance to minimize deficit-revealing conditions.

Compensation is the term applied to a third interpretation of reduced age differences with experience because a loss in one aspect of processing could be balanced by a gain in another aspect of processing. This interpretational category differs from the previous ones in that a clear exchange is implied in which an inferiority in one processing component is accompanied by a superiority in another aspect of processing.

Notice that although remediation, accommodation, and compensation could each be responsible for interactions of age and experience, only remediation actually results in an alteration in the critical aspect of processing responsible for the initial performance differences. Because this is probably the most common interpretation of such an interaction, it is desirable to examine relevant evidence carefully to determine the plausibility of remediation as opposed to accommodation or compensation. This was an explicit goal of the study investigating the effects of practice on age differences in performance.

The study, described more fully in Salthouse and Somberg (1982), involved samples of young (age 19 to 27 years) and old (age 62 to 73 years) adults performing four distinct perceptual-motor tasks for 50 1-hr sessions over a period of several months. The tasks were embedded in a video-game context to maintain motivation across sessions, and the participants also received a bonus payment equivalent to their previous total compensation upon completion of all sessions as an incentive for continued participation. Although the subjects performed four different tasks, the one of greatest interest in the present context was a memory-scanning reaction-time task. The other tasks involved signal detection, visual discrimination, and temporal prediction of the intersection of two trajectories; but performance in the first two tasks was limited by ceiling effects in the data from the young subjects, and the measures in the third task had low reliability because they were based on a very small number of observations in each session.

A trial in the memory-scanning task consisted of the presentation of from one to four different symbols as the memory set, with the subject requested to determine as rapidly as possible whether a probe stimulus had been a member of that earlier presented memory set. Two parameters can be used to summarize performance on this task—the mean reaction time across the different set sizes, reflecting the overall level of performance, and the slope of the function relating reaction time to number of items in the memory set. This latter measure has been interpreted as an index of the time needed to perform a single comparison of an item in memory (Sternberg, 1975), and has been found to decrease considerably as a function of practice in samples of young adults (Schneider & Shiffrin, 1976).

The major results of this project are illustrated in Figure 1. This figure contains the mean reaction-time data across the 50 experimental sessions, and also the results from a 51st session administered 30 days after the 50th session. The functions are somewhat irregular because of a number of transfer conditions administered to determine the

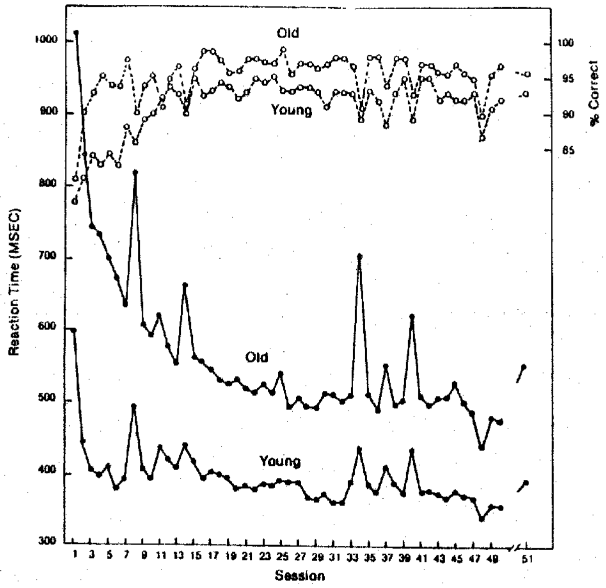

Figure 1. Mean reaction time in the memory-scanning task for young and old adults as a function of practice. Figure from "Skilled Performance: The Effects of Adult Age and Experience on Elementary Processes" by T. A. Salthouse & B. L. Somberg, 1982, Journal of Experimental Psychology: General, 111, p. 188.

of switching the stimulus set, reducing the size of the probe stimuli, and so on, but it is clear that the age differences remain remarkably constant throughout 50 hrs of practice. At least with the measure of overall mean reaction time, therefore, these results suggest that the magnitude of age differences in performance are relatively stable across moderate amounts of experience. The apparent implication is that practice-related factors cannot account for much of the initial age differences in perceptual-motor performance because those differences are not substantially altered even when the individuals in each age group received practice sufficient to achieve near-asymptotic levels of performance.

The results from the slope measure were somewhat different, however, as the initial age differences were greatly attenuated, if not actually eliminated, by moderate practice. The slopes based on reaction times across set sizes 2, 3, and 4 in sessions 2 through 5 were 57.0 ms per item for the older adults and 16.5 ms per item for the young adults, but these were reduced to 15.0 and 13.5, respectively, in sessions 42 through 45.

How is the convergence of the slopes of young and old adults with practice to be interpreted? Three possibilities were outlined earlier—remediation, accommodation, and compensation. Because the slope parameter seems to reflect a unitary process, that is, the duration of a single memory comparison, the gradual reduction of the age differences could be explained as remediation of the age-related slowing deficit in this process. Accommodation and compensation are not as plausible unless an alternative means of accomplishing the memory comparison process can be identified. However, another possibility is that the age differences were attenuated because the component process indexed by the dependent variable was gradually phased out in the course of practice on the task. A commonly accepted interpretation of practice-mediated reductions in memory-scanning slope is that after extensive practice with the same assignment of stimuli to responses the memory scanning becomes automatic, possibly because of a more direct linkage between target stimulus and response category. From this perspective, therefore, the slope results imply that young and old adults are equally adept at developing automaticity of memory scannning, and consequently that the age differences are attenuated when the importance of processes responsible for those differences is greatly reduced.

This latter interpretation suggests that a category of *elimination* might be added to those of remediation, accommodation, and compensation as potential mechanisms to account for convergent interactions of age and experience. That is, if the critical processes responsible for the dependent variable cease to contribute to performance after moderate amounts of practice, then the age differences can be considered to be reduced because the relevant component has been eliminated.

To summarize, no interaction of age and experience was apparent in the measure of overall reaction time, but the age differences were reduced with practice on the slope measure. Because the slope is presumed to reflect the single process of memory scanning, accommodation and compensation interpretations seem rather implausible. However, because of the possiblity that the memory-scanning operation was eliminated after moderate practice, it is still not certain whether the interaction with the slope measure should be considered evidence of remediation of age differences in performance.

Although the results of this practice study were interesting, the study has at least two important limitations. One is that the simple nature of the experimental tasks biases the results against certain potential outcomes. For example, there is little possibility for a compensatory mechanism to emerge in very simple tasks such as choice reaction time. More complex activities in which there are a variety of different ways of performing the overall task are presumably necessary in order to provide a fair test of the compensation interpretation.

A second limitation of this, and virtually any, practice study is that it could be argued that the amount of practice provided was insufficient, and that with additional practice a different pattern of results might emerge. This is an extremely difficult criticism to overcome in studies manipulating practice in the laboratory because the amount of experimentally provided experience is necessarily limited, and yet there appear to be no limits in the amount of additional practice which continues to lead to improved performance. In other words, only a relatively small amount of practice can be administered in experimental situations, and yet performance improvements may continue indefinitely (although at progressively smaller rates) with increased practice.

In light of these reservations, it seemed desirable to consider an alternative means of investigating the effects of experience on age differences in performance. The procedure adopted capitalizes on naturally occurring experience with reasonably complex, but experimentally decomposable, real-world activities.

MOLAR EQUIVALENCE-MOLECULAR DECOMPOSITION

The molar equivalence–molecular decomposition research strategy is a variant of a procedure introduced by Charness in his studies of skilled bridge and chess players (e.g., 1979, 1981, 1983). The first step in this procedure is to obtain a moderately sized sample of adults with a wide range of ages, and across many different levels of competency on the task of interest. By careful selection of the research participants it is generally possible to obtain a sample in which the correlation between age and performance on the composite task is near 0, that is, one in which the average level of molar competency is equivalent across the age span. Unlike the case with the experimental manipulation of practice where the goal is to examine performance after ostensibly comparable amounts of practice, it is expected in this procedure that achievement of the same level of proficiency across adulthood probably requires that age and experience are positively correlated, that is, that the older adults have had more relevant experience than the young adults. However, if the activity can then be decomposed into its molecular components, age trends on the proficiency of selected components can be examined to determine the means by which a given level of molar competency is achieved at different ages. Note that the important question in this context is not what effects age has on the molar behavior, but rather whether identical mechanisms are used by all age groups to achieve the same overall level of performance.

Two outcomes from the molar equivalence–molecular decomposition strategy are particularly interesting. One pattern of results, which might be termed the *maintenance hypothesis*, is that the equivalence of molar performance is achieved because the greater experience associated with increased age leads to maintained proficiency of molecular components rather than the typical age-associated decline. In other words, the expected age-related reduction in effectiveness of molecular processes may have been prevented by the positive relationship between age and experience with the composite task. This hyothesis is consistent with both the remediation and the accommodation interpretations discussed above since experience may have "remedied" the age-related deficit found in unexperienced adults, or many older adults may have accommodated to their deficit and selected themselves out of, or into, certain occupational settings. Accommodation in this instance implies that the older adults who have continued in the relevant activity may not be very representative of their age groups, and thus the absence of an expected age difference in the molecular components may be due to differential representativeness with more highly selected individuals in the older age groups.

A second possible outcome with the molar equivalence–molecular decomposition strategy is designated the *compensation hypothesis* since a typical age-related decline might still be evident in molecular proficiency, but this decrease could be compensated for by increases in the effectiveness or efficiency of one or more metacomponential mechanisms. The nature of the metacomponential mechanisms will obviously vary across activity domains, but it will be compensatory to the extent that operation of these mechanisms allows the attainment of a high level of global proficiency despite reductions in the efficiency of component processes.

Transcription typing was the activity selected for investigation in the molar equivalence–molecular decomposition study (described in more detail in Salthouse, 1984). Three factors were influential in this decision. First, the discrete nature of the keystroke responses makes it reasonably easy to investigate. That is, typing appears integrated and continuous, and yet it culminates in distinct and separate keystrokes which can be easily timed and evaluated.

Second, the widespread use of typewriter keyboards provides access to subject populations of all ranges of skill and age. Moreover, the variations in skill can be orders of magnitude greater than that possible in laboratory tasks because of the immense amount of natural experience preceding practice study involved 50 separate experimental sessions, the total number of reaction-time trials per subject was only 5,000. An average professional typist would execute this many keystrokes in about 17 min. and might be expected to produce over 2.5 million keystrokes each year.

The third reason for selecting typing as the molar activity in this study was that the activity of typing seems decomposable into components related to choice reaction time, tapping speed, and digit symbol substitution speed. For example, in both choice reaction time and transcription typing tasks the individual is required to view visually presented characters, encode them, translate them into approriate finger movements, and then execute the movements to press the appropriate key as rapidly as possible. Tapping speed is a plausible component in typing because the speed of typing is clearly limited by the rate at which one can repetitively move one's fingers. The rate of digit symbol substitution is not as obviously related to typing speed, but is similar in that both the substitution of digits into symbols and the manual typing of visually presented letters involve the rapid transcription of information presented in one form into corresponding information in another form.

The study, actually two separate studies involving very similar procedures with different samples of 34 and 40 adults, consisted of administering timed tests of transcription typing from printed copy as well as a number of specially designed tests measuring components such as reaction time, tapping speed, and digit symbol substitution rate. The typists ranged between 19 and 72 years of age and between 17 and 104 net words per min., but with no overall correlation between age and net words per min. (i.e., *r* = .07 for Study 1, and *r* = −.10 for Study 2). Age was positively correlated with cumulative experience, however, as the older typists had a greater number of months of typing-related employment than did the younger typists (i.e., *r* = .51 for Study 1, and *r* = .55 for Study 2).

Correlations between measures of component proficiency and molar competency (i.e., typing performance in net words per min), and between component proficiency and age are displayed in Table 1. The major point to be noted from these data is that the correlations with typing skill are opposite in direction to those with age. This suggests that while proficiency in the molecular processes is associated with better performance on the criterion typing task (i.e., higher typing speeds are associated with shorter reaction times or tapping intervals, and with more digit symbol substitutions), increased age is a disadvantage with each of these measures.

Table 1. Component Process Correlations

	Net Words per Min		Age	
	Study 1	Study 2	Study 1	Study 2
Choice reaction times	−.18	−.36	+.46	+.62
Tapping interval	−.43	−.43	+.40	+.52
Digit symbol substitution rate	—	+.53	—	−.55

Another illustration of this phenomenon is presented in Figure 2, which portrays the mean interkey interval for reaction time and typing as a function of the age of the typist. (The data for this figure, and those for Figures 3, 4, and 5, are based only on the 56 typists with typing speeds above 45 net words per min to ensure that all typists were at least moderately proficient.) Notice that reaction time exhibits a sizable age trend of approximately 136 additional ms per keystroke between the 20s and 60s, whereas the age trend in typing interkey interval is virtually nonexistent. This pattern of results is clearly consistent with the compensation hypothesis described earlier since these individuals exhibited typical age-related declines in measures of component proficiency, and yet were still able to achieve the same level of molar competency.

What are the compensatory mechanisms used by older typists to achieve high levels of typing speed despite the handicap of a slower perceptual-motor speed? Several possibilities were investigated in this project, but only one measure was found to be significantly related to age. An initial hypothesis was that older typists might have developed a greater sensitivity to letter frequencies than did young typists and thus could compensate for their slower perceptual-motor speed by better matching their keystroke efficiency to the probabilities of specific letters and sequences of letters. This possibility was investigated by determining the correlation between age and measures of the effects of letter or letter-pair frequency on interkey interval during normal typing. These correlations did not differ significantly from 0, therefore suggesting that greater sensitivity to letter frequencies is unlikely as the compensatory mechanism responsible for older adults achieving the same level of typing speed as young adults in the presence of declines in the efficiency of component processes.

A second possible compensatory mechanism was the consistency of the interkey intervals during typing, on the assumption that the older experienced typists might have learned to type each keystroke at approximately equal intervals. This hypothesis was also not supported, as the correlations between age and variability of interkey interval while typing were uniformly low and not significantly different from 0.

The third compensatory mechanism investigated was the extent of

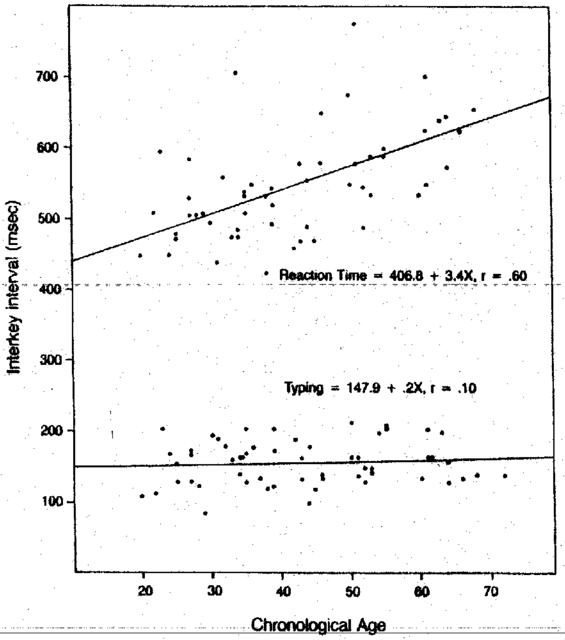

Figure 2. **Median interkey intervals in choice reaction time and normal copy typing as a function of typist age.**

anticipatory or preparatory processing carried out while performing normal typing. It was hypothesized that older typists might have learned to expand their "span of processing," thereby increasing the time during which a particular character can be processed. The means by which this anticipatory processing mechanism was investigated involved a special task in which typists were asked to type material from a video monitor arranged such that only a limited number of characters appeared at any given time. The number of characters, which was termed the preview window, ranged from 1 to 11 characters in increments of 2. With each successive keystroke the leftmost character was removed from the screen, the remaining characters each shifted one space to the left, and another character was added to the right of the display.

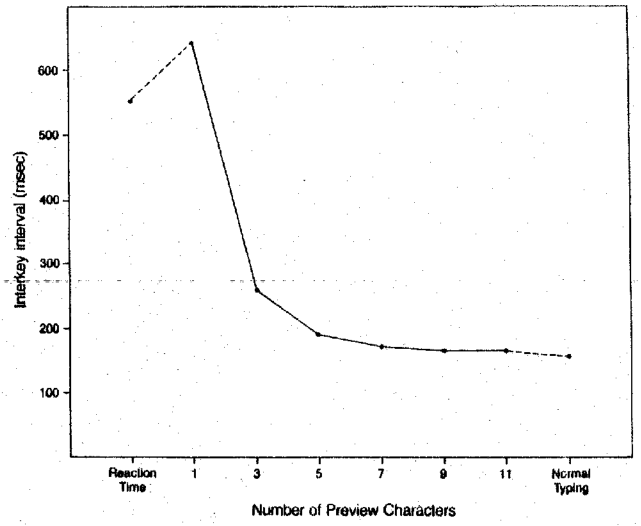

Figure 3. **Mean, across typists, of median interkey intervals in normal copy typing, typing with preview windows of 1 to 11 characters, and choice reaction time.**

a horizontally scrolling text since the material shifted at a rate determined by the interval between successive keystrokes.

Under conditions such as these, the rate of typing becomes slower with a reduction in the number of visible characters, particularly when fewer than five characters are present in the display. The value of this manipulation is that the largest preview window at which typing rate is first disrupted compared to normal typing can be used as an index of the extent of advance processing employed in normal typing. That is, if typing rate is slower with a given number of preview characters relative to normal typing, then when maintaining his or her normal rate of typing the typist must normally process more than the displayed number of characters.

The mean interkey intervals for the six preview window conditions employed, and for the typing and choice reaction time tasks, are displayed in Figure 3. Notice that the typists are performing at their normal typing rate with preview windows of 7, 9, and 11 characters, but that their performance becomes progressively more impaired with

These results indicate that performance systematically varies from that characteristic of typing with large amounts of preview, to that characteristic of reaction time with preview limited to a single character. One can therefore infer that the relatively high rates of performance of normal typing are achieved in large part because of the simultaneous processing of several characters in advance of the character to be typed. Judging from the average results displayed in Figure 3, we find that the typists in the current sample were processing between three and four characters in advance of the character whose keystroke was being pressed since their rate did not reach the level of normal typing until at least five characters were simultaneously visible on the display.

Effects of age on this measure of anticipatory processing were examined in two complementary analyses. One was based on the correlations between age and interkey interval across the various preview conditions. The relevant correlations are illustrated in Figure 4. Notice that the correlations are virtually identical to those obtained in the choice reaction time and typing tasks at preview windows of 1 and 11, respectively, and that they systematically change from one to the other with increased preview. The age-related slowness in processing therefore becomes progressively less important as the number of preview characters is increased, culminating in no age relationship with normal typing. The apparent implication is that with increased age there is a greater reliance on anticipatory preparation which serves to minimize the limitations of slower perceptual-motor processes.

Another analysis conducted to determine the effects of age on anticipatory processing involved determining the number of characters needed to maintain a normal rate of typing for each typist, and then plotting this variable as a function of the age of the typist. As mentioned earlier, the preview-window size at which the typing rate first increases, by a criterion amount, above the rate of normal typing can be taken as a measure of the number of characters normally used in typing. I call this quantity the eye-hand span because it indicates the gap between the character whose key is currently being pressed and the character currently receiving the attention of the eyes. Figure 5 illustrates the relationship between typist age and eye-hand span in this sample of typists. Notice that there is a significant increase with age in the size of this running memory span. Typists in their 60s are relying upon an average of 4.8 characters to the right of the character being typed, while those in their 20s depend upon an average of only 2.4 characters. The difference of 2.4 characters translates into approximately 380 ms of additional preparation time available to typists in their 60s compared to typists in their 20s. This is nearly three times greater than the reaction-time differences expected across this age interval and appears more than sufficient to compensate for the slower perceptual-motor processes.

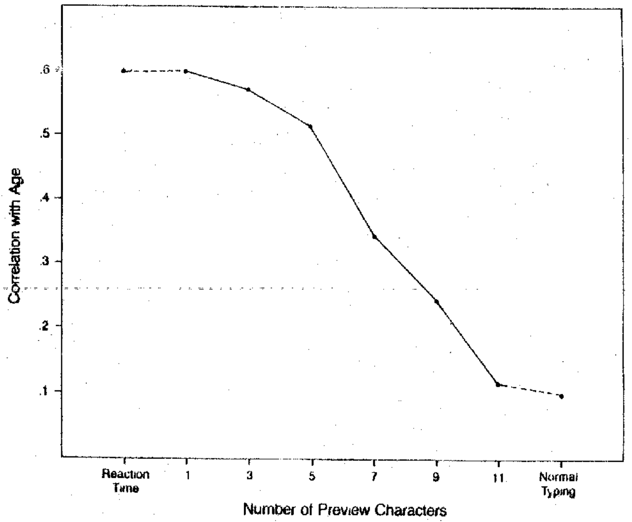

Figure 4. **Correlations between typist age and median interkey interval in normal copy typing, typing with preview windows of 1 to 11 characters, and choice reaction time.**

The results of this typing project provide an intriguing example of the potential contribution of the molar equivalence–molecular decomposition research strategy. Young and old typists did not differ in their overall level of typing proficiency, but they were distinguishable in terms of the way in which this proficiency was achieved. Despite experience extending to decades and many millions of keystrokes, the older typists were slower at several perceptual-motor processes than were younger typists. In this respect these results are consistent with those of the practice study since the age differences are not eliminated even when the amount of experience greatly favors the older adults. However, the apparent handicap of slower perceptual-motor processes did not impair overall performance of the older typists because they seem to have adopted a strategy of anticipating more impending characters than did young typists, thereby allowing them to compensate by expanding the temporal interval over which processing could occur.

More extensive planning and preparation

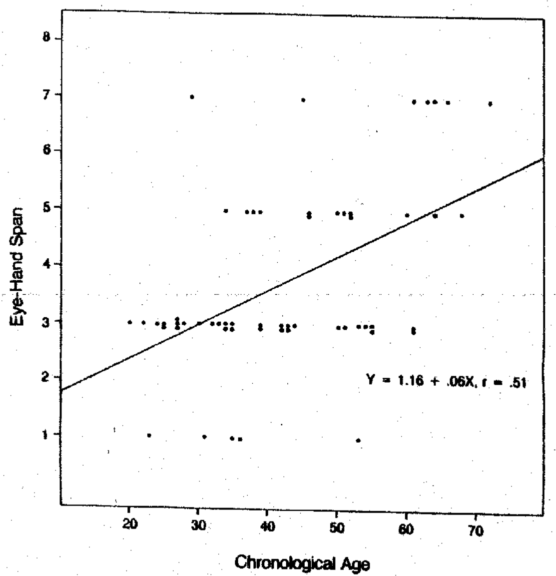

Figure 5. **Eye-hand span, inferred from the largest preview window at which typing rate first deviates from that of normal typing, as a function of typist age.**

is an interesting and intuitively compelling compensatory mechanism. However, quite different mechanisms might be employed in other domains and thus it is desirable to extend the molar equivalence–molecular decomposition research strategy into other ability areas.

CONCLUSION

The studies described above are concerned with only a single activity domain, and even then involved a far from exhaustive examination of important processes and mechanisms. Nevertheless, reliance on two different approaches to the issue of age and experience allows stronger and more generalized conclusions than those that would be possible if only a single research strategy had been employed.

A major conclusion is that the lab-life discrepancy in inferred age trends in cognitive competence might indeed be explainable in terms of differential experience. Adults of all ages appear to benefit from experience, and in at least one activity older adults have been found to compensate for declining abilities and thus still maintain a proficient level of overall performance.

As with most studies, however, the results have led to the generation of many new and intriguing questions. For example, it is still not known whether age-related deficits in important cognitive abilities can actually be remediated, as opposed to being accommodated or compensated, through experience. The circumstances responsible for maintenance rather than compensation of extensively practiced activities are also unclear. And finally, the nature of compensation remains a puzzle, particularly the relationship between the mechanisms employed by older adults and those used by highly skilled individuals of any age.

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