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CHAPTER 3

General and specific age-related influences on neuropsychological variables

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Introduction

Cross-sectional comparisons of people of different ages assessed at the same point in time consistently reveal age-related declines on many different neuropsychological variables in the absence of overt disease. As an example, Fig. 1 illustrates the age relations in four frequently used neuropsychological variables from studies summarized in Mitrushina, Boone and D'Elia (1999). The data in the figure were based on studies with a minimum of 15 individuals in each of two or more age groups differing by at least 15 years. It can be seen that increased age was associated with more errors in the Category Test, slower completion time in Version B of the Trail Making Test, and lower performance in the Logical Memory and Visual Reproduction tests. In addition to the results with these four tests, age-related effects have consistently been reported in variables hypothesized to reflect attention, memory, visual–spatial processing, abstraction, and executive functions (see reviews in: Craik and Salthouse, 2000; LaRue, 1992; Lezak, 1995; Mitrushina et al., 1999; Spreen and Strauss, 1998; and Tuokko and Hadjistavropoulos, 1998). A key question for researchers interested in aging is how these findings are to be interpreted. Different biases about the nature of possible interpretations, one emphasizing specific explanations and the other general explanations, originate from different traditions in psychology.

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Specific

A succinct description of a research tradition that favors specific explanations for cognitive and neuropsychological functioning was provided by Sergent: "More than a century of research has firmly established that the brain is organized into distinct areas of relative functional autonomy and specialization, and that local cerebral damage results in selective impairment of mental functions" (Sergent, 1988, p. 69). In other words, considerable research on brain-damaged patients suggests that there is localization, or modularity, of many cognitive functions (e.g., Kertesz, 1994). Discrete lesions have been found to have specific types of behavioral impairments, such as damage to Broca's area disrupting language production, and damage to the medial temporal and hippocampal complex affecting many aspects of memory. Furthermore, functional neuroimaging activation patterns are also consistent with the localization assumption because certain cognitive tasks have been found to be associated with regionally specific activation. When considered together, therefore, the lesion and neuroimaging evidence strongly suggest that different brain regions are involved in the performance of particular neuropsychological tasks.

Although it does not necessarily follow, the reverse is also sometimes inferred to be true in that

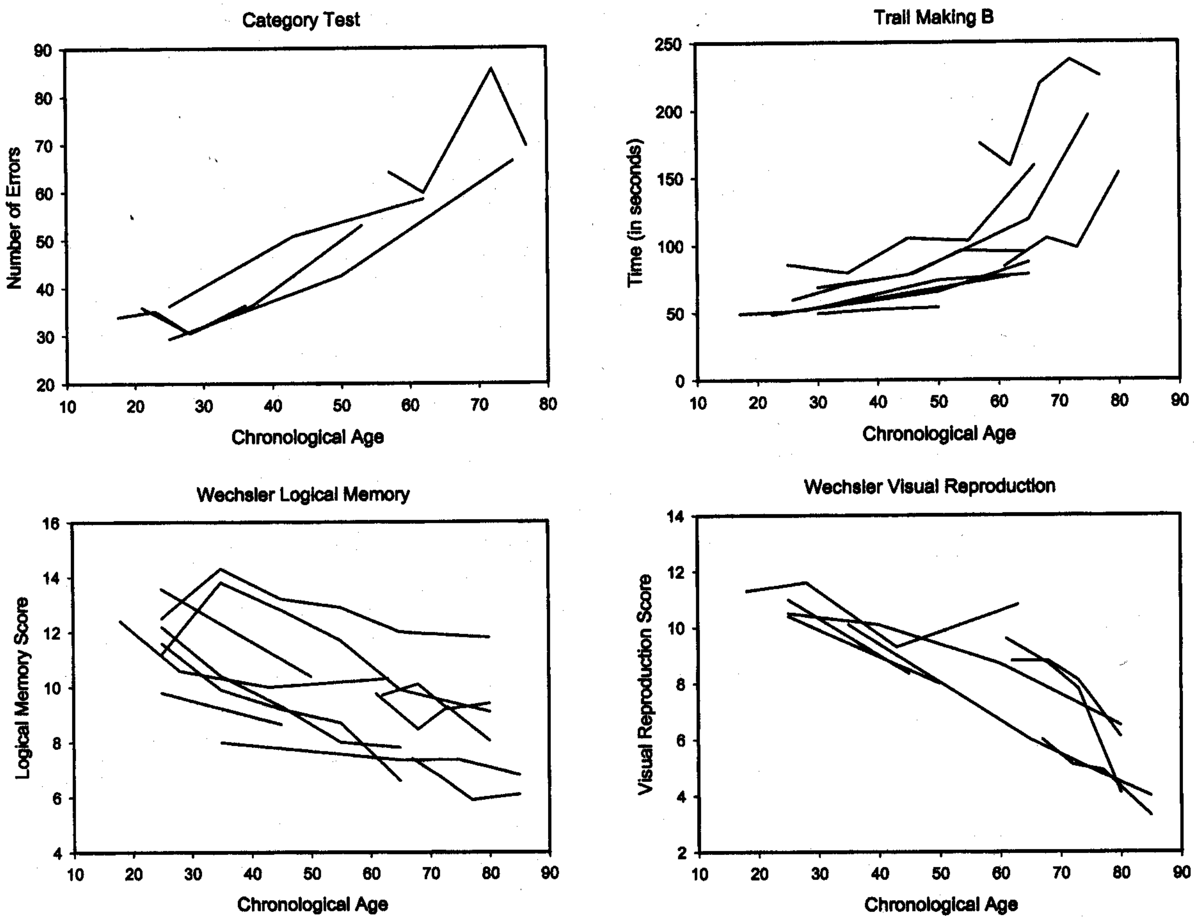

Fig. 1. Mean levels of performance in four neuropsychological tests as a function of age. Each line corresponds to results from a different study. Data from values reported in Mitrushina et al. (1999).

scores in certain tasks are postulated to reflect the level of functioning in particular neuroanatomical regions or structures. For example, there is frequent reference to 'frontal tasks' such as the Wisconsin Card Sorting Test (WCST), Trail Making B, and various tests of fluency or controlled associations, because of reports that people with damage to the frontal lobes are impaired on these tasks. However, the practice of using performance on one or more neuropsychological tasks as the basis for speculations about the integrity of particular neuroanatomical regions or structures has been criticized because although the tasks may be sensitive to damage in selected regions, performance on the tasks is not necessarily specific to those regions since damage to other regions can also disrupt performance and it is also the case that not all patients with damage to these regions exhibit compromised performance (e.g., Anderson, Damasio, Jones, and Tranel, 1991; Mountain and Snow, 1993; Reitan and Wolfson, 1994, 1995; Vallar, 1991). Nevertheless, the practice of referring to tasks or variables in terms of their purported neuroanatomical localization indicates how strongly the localization perspective has been incorporated into the thinking of many researchers.

At the current time it is beyond dispute that at least some modularity of cognitive function exists. An important question with respect to normal aging is how the discovery of age differences in a wide variety of variables can be accommodated within the localization or modularity framework. One possible implication of this perspective for interpreting age differences is that age-related effects on different variables are attributable to discrete effects on specific neuroanatomical structures, and each compromised function should ultimately be traceable to a deficit in the structure or region specialized for that function.

General

A different tradition relevant to how age differences in cognitive and neuropsychological variables might be interpreted is the psychometric perspective. One of the most striking phenomena within the psychometric literature is the 'positive manifold' phenomenon, which refers to the fact that most cognitive variables are positively correlated with one another when their reliabilities are high and the range of variation is not restricted. The positive correlations are often interpreted in terms of the operation of various higher-order factors, up to and including the level of general cognitive ability, or Spearman's *g*.

Similar patterns of moderate positive correlations have been found among neuropsychological variables in samples of healthy adults across a wide age range. Correlational data of this type have been reported many times (e.g., Aftanas and Royce, 1969; Daigneault, Braun and Whitaker, 1992; Schuldermann, Schuldermann, Perryman and Brown, 1983), but the phenomenon can be illustrated with data from a study by Salthouse, Fristoe and Rhee (1996) involving a sample of 259 adults between 18 and 94 years of age. A correlation matrix with a larger number of variables was reported in the original article, but for the present purpose it is sufficient to consider only correlations among four variables typically assumed to represent different neuropsychological functions. The relevant values are presented in Table 1, where it can be seen that all correlations are significantly different from zero. These results indicate that the variables are not independent of one another, and as will be discussed later, other evidence suggests that the age-related influences on the variables are also not independent.

TABLE 1

Correlations among four neuropsychological variables in a sample of 259 healthy adults in a study by Salthouse et al. (1996)

	WCST	RAVLT	BlkDes	Trails B
WCST (Per. Err.)	–	0.27	0.47	0.49
Rey AVLT (Trial 2)		–	0.30	0.40
WAIS Block Design			–	0.50
Trail Making B				–

Note: WCST is the measure of perseveration errors in the Wisconsin Card Sorting Test, RAVLT is the number of words recalled in the second trial of the Rey Auditory Verbal Learning Test, BlkDes is the score on the Block Design subtest from the Wechsler Adult Intelligence Scale, and Trails B is the time to complete version B of the Trail Making Test.

The existence of positive correlations among neuropsychological variables appears to have been neglected in much of the neuropsychological literature concerned with normal aging. One possible reason is that relatively few studies have examined two or more variables presumed to reflect different constructs or functions in the same sample of participants. Other reasons may be related to methodological factors. For example, relations among variables may not be detectable if the samples are small, if the range of variation in the scores is restricted, or if the reliability of the variables is low. The power to detect correlations of a given magnitude varies with sample size, and thus moderate correlations may not be identified as significant with small samples. Correlations may also be artificially reduced when the variability in the sample is much smaller than that in the population of interest. If a standardized test is administered, one means of determining whether the correlations might be attenuated due to restriction in range is to compare the standard deviations in the experimental sample with those for the appropriate age range in the sample used to establish the norms for the test. Finally, information about the reliability of the variables is critical for meaningful interpretation of correlations because an uninteresting explanation for a low correlation is that it is attributable to lack of reliability in one or more variables. It should also be noted that methodological factors can operate to produce significant correlations that are misleading because a significant correlation might be attributable to a few extreme cases. Formal methods to detect outliers may not be very sensitive when the samples are small, but correlations can be computed with and without the suspect case, and then both values reported to allow the influence of that case to be evaluated.

There are at least two implications of the presence of positive correlations among what are hypothesized to be different types of variables. First, because a wide variety of variables are interrelated to one another, researchers need to be cautious in using the existence of a correlation to infer that variables are similar in one particular respect, such as dependence on a specific neuroanatomical region (see the criticism of "second-order localization" in Salthouse et al., 1996). That is, a simple correlation can occur for a number of reasons, and thus a correlation should not be attributed to a single factor or characteristic without additional supporting information. To illustrate, a moderate correlation (i.e., $r = 0.50$) is apparent in Table 1 between the Block Design and Trail Making B variables, but it is not necessarily due to involvement of the same neuroanatomical region because it could be a reflection of the fact that both tasks require planning, use of spatial abilities, manual dexterity, and perhaps other common processes.

And second, the existence of positive correlations among variables suggests that it is important to determine the level of generality at which age-related influences operate. That is, because of the large number of variables that have been found to be negatively associated with age, it is important to consider the question of how to interpret age-related effects on one variable in the context of age-related effects on many other variables and the positive correlations among variables. In other words, a critical issue that needs to be addressed is whether the age-related effects are unique to a particular variable, or are simply another manifestation of some type of broader phenomenon.

Anderson (1956, p. 77) raised this issue over 40 years ago in the following passage: "Is there an overall commonality in decline which can be used as a base from which to analyze the decline of particular parts or structures or is it the summation of a host of specific declines?" A similar concern was mentioned more recently in another context by Baddeley (1996, p. 19): "One problem in attempting to carry out theoretically driven studies on ageing stems from the fact that almost every physical and cognitive function shows some decline. Consequently, showing that the elderly perform poorly on any given task cannot be regarded as evidence for the task's peculiar vulnerability to ageing, unless other factors are ruled out."

These comments are related to a distinction between general and specific age-related influences on cognitive and neuropsychological variables. The issue of general versus specific effects has been discussed in neuropsychology (e.g., Reitan and Wolfson, 1996; Sergent, 1988), but there is still little agreement about how the two types of influences can be distinguished, or the best manner in which their contributions can be assessed.

At least two factors are probably responsible for the continuing controversy regarding specific and general influences. First, many researchers have emphasized all-or-none positions that are either completely specific (modular) or completely general (holistic), rather than attempting to assess the relative contributions of each type of influence. And second, the term specific has been interpreted in a variety of ways, and although they are all related, each has a slightly different meaning, and has been investigated with somewhat different methods. In the following sections four different usages of the term specific in the context of research on aging (i.e., conditional, selective, particular, and unique) are discussed, and the analytical methods used for their investigation critically evaluated. It will be argued that much of the previous research in the field of aging has relied on unnecessarily restricted conceptualizations of specific influences, and that consideration of alternative conceptualizations and analytical procedures may lead to greater insight into the nature, and ultimately the cause, of age-related effects in cognitive functioning.

Specific as conditional

One usage of the term specific is in connection with analysis of variance (ANOVA) designs in which age is one factor, and variable (or task) is another factor. The main effect of age can be interpreted as a reflection of its general influence on both variables. However, an interaction of age and variable can be interpreted as a specific age-related effect because it indicates that the age effects are not uniform across variables, but instead are conditional on the variable under investigation. Non-additive effects in ANOVA can therefore be viewed as variable-specific (or task-specific) influences.

ANOVA interactions clearly indicate that the magnitudes of the age-related effects differ across variables, but they are a relatively weak form of specificity because of a number of complications associated with the interpretation of interactions. For example, interactions can be influenced by measurement artifacts of floor or ceiling, and by differences across variables in discriminating power (cf., Chapman and Chapman, 1973). Furthermore, only disordinal (cross-over) interactions are robust across various transformations, and because the true relation of the variable to the construct is generally not known, many transformations might be justified which could either create or eliminate interactions (see Salthouse, 2000, for further discussion).

Specific as selective

Within the field of neuropsychology researchers often rely on dissociation or double dissociation logic to identify specific effects (see Vallar, 1991, for discussion). In simple dissociation, factor A affects variable 1 but not variable 2 (or in a weaker version, the effects on variable 1 are larger than those on variable 2), and therefore factor A appears to be selective, or specific, in terms of its effects.

Simple dissociations can be viewed as functionally equivalent to the discovery of a significant interaction in ANOVA, and some of the same concerns associated with the interpretation of ANOVA interactions have been raised with respect to simple dissociations. In particular, the apparent selectivity may be not be real because it could be attributable to differences across variables in discriminating power, such that some variables are simply more sensitive or reliable than others (cf., Chapman and Chapman, 1973). In recognition of these problems, the double dissociation procedure is often advocated in which factor A affects variable 1 but not variable 2, and another factor, B, affects variable 2 but not variable 1. If a differential pattern such as this were to be found, lack of sensitivity could be ruled out as the explanation for the selective influence of factor A on variable 1. Double dissociation patterns therefore provide strong evidence for a specific, in the sense of selective, influence of factor A on variable 1. (However, see Sergent, 1988, for discussion of some limitations of the double dissociation methodology.)

Double dissociation logic has been used in the interpretation of research on aging when age-related effects are found on one variable, such as free recall, but not on another variable, such as a measure of priming. In contrast, another factor, such as semantic relatedness of the words, may affect the magnitude of priming, but have little or no effect on the number of words recalled in a free recall task. A pattern such as this would likely lead to a conclusion that the measure of priming is not generally insensitive, but rather is selectively insensitive to the age 'factor'.

However, interpretation of double dissociation results can become complicated when, as in the situation just described, one factor is manipulated between subjects and the other is manipulated within subjects because for a given factor sensitivity in the two types of comparisons may be negatively related. That is, sensitivity in between-subject comparisons (e.g., age differences) is limited by the reliability of the variable, which is typically based on the correlation between similar items or parallel forms, and other things being equal, correlations are directly proportional to the range of between-person variation in the variables. Reliability in between-subjects comparisons is therefore greater with *increases* in between-person variability in the relevant measure. However, in within-subject comparisons increases in the sensitivity of the task effect (e.g., the priming manipulation) are associated with *decreases* in between-person variation in the magnitude of the effect because this quantity, in the form of the subjects-by-effect interaction, serves as the denominator in the statistical test. That is, because the *F*-test for a within-subjects manipulation is the ratio of the mean square for the effect of the manipulated factor to the mean square for the interaction of subjects with the effect of the manipulated factor, both the ratio and the *F* value increase as the between-subjects variation in the magnitude of the effect decreases. It is therefore somewhat paradoxical that the more robust a phenomenon in a within-subjects manipulation, the lower its potential reliability, and hence sensitivity, in a between-subjects comparison. An important implication of this observation is that in order to ensure that the variables are equivalent in discriminating power for between-subject comparisons, reliability should be computed for each variable in the sample under investigation, and equal sensitivity of the variables should not merely be assumed on the basis of results from within-subjects comparisons.

Specific as particular

It is sometimes assumed that the issue of general versus specific influences can be resolved by relying on the principle of subtraction. The rationale is that if two tasks presumed to differ in a single aspect are compared, then effects operating on both tasks can be assumed to be relatively general, whereas any age-related effect on the difference between the two tasks is necessarily specific, in the sense that it operates on the particular aspect that distinguishes the two tasks. The relevant data can be analyzed in an ANOVA with the focus on the interaction term, or with other statistical procedures such as a *t*-test on the difference score, but the critical characteristic of subtractive logic is that the variables are selected because of theoretical assumptions about how the tasks differ from one another. The reasoning can be traced back to the subtraction method introduced by Donders, and the logic has been incorporated in many neuropsychological tests, such as the Stroop Color-Word Test, the Trail Making Test, and contrasts of immediate and delayed recall, figure copy and figure memory, etc.

The subtraction method has been criticized for its reliance on the assumption of 'pure insertion', namely, that the tasks under investigation differ only in a single critical aspect. This concern is particularly relevant with several common neuropsychological tests because the different tasks or conditions often differ in a number of ways, and it is not obvious which of those differences is (or are) primarily responsible for the observed performance differences between them. As an example, consider the A and B versions of the Trail Making Test. In the conventional administration of the test, Version B is always administered second, it includes letters not used in version A, and the path to connect the targets is longer in version B than in version A. These types of confoundings can be corrected (e.g., Salthouse and Fristoe, 1995; Salthouse, Toth, Daniels et al., 2000), but in the typical usage of neuropsychological tests few comparisons are unambiguously interpretable in terms of the operation of a single aspect.

Two other limitations of the subtraction procedure are often not recognized. First, reliability of difference scores may be low because they are inversely related to the correlation between the two variables used to derive the difference. In other words, the more closely two variables are related to one another, the smaller the variance in a measure of the difference between them, and hence the lower the likely reliability of the difference score. This is a potentially serious problem in studies of aging or other types of individual differences because if the reliability of the variable is low, then it may be difficult to detect group differences that really exist.

And second, despite one's intuition, difference scores are not independent of the original values, and instead are negatively correlated with the initial score, and positively correlated with the subtracted score (see Cohen and Cohen, 1983, pp. 415–416). Therefore, if the goal is to obtain a variable that is unrelated to the original variables, and presumably directly reflects what differs between the two variables, it has been recommended that multiple regression procedures be used to create residuals in which the variance of the simpler variable is removed from the more complex variable (e.g., Cohen and Cohen, 1983). The residual variable that results from this regression procedure will be statistically independent of the simpler variable because it represents variance in the more complex variable that is not shared with the simpler variable.

Although the use of residuals has a number of advantages over the use of difference scores, it has the disadvantage of requiring moderately large samples to obtain stable regression coefficients. For example, it is sometimes suggested that a minimum sample size of 50 to 100 individuals is necessary for a meaningful regression analysis, with increases of 10 to 15 individuals for each additional predictor variable in the regression equation.

Specific as unique

The argument for the use of residuals can be generalized to many comparisons, and is not simply restricted to tasks originally designed for use with the subtraction method. That is, when statistical techniques are used to control the effects of one variable, it is possible to determine the extent to which the age-related effects on a second target variable are specific, or unique, to that variable. For example, given that a factor, such as age, has been found to have effects on several different variables, one can ask to what extent the age-related effects on the different variables are independent of one another, or are shared with other variables. This usage of the term 'specific' is most similar to Baddeley's reference to 'peculiar' in the quotation cited above, in that specific refers to unique or independent influences of age (or whatever factor is of interest).

This conceptualization of specific is important in research on aging because it is relevant to the nature of the explanations that will ultimately be required to account for age-related effects. That is, age-related effects on a given variable could be conditional, selective, and particular, but if they are not unique to that variable then they may simply be another manifestation of a broader phenomenon. In other words, age-related effects could be differential in the sense that they vary in magnitude across variables, but the influences on different variables are not necessarily independent of one another because they could reflect differential reliance on a common process or factor (see Salthouse and Coon, 1994, for further discussion of this point).

Uniqueness or independence of age-related influences on the variables of interest can be evaluated with a variety of residual analysis procedures. Most of these procedures also have the desirable property of providing quantitative estimates of the proportions of unique and shared age-related variance, making it possible to determine the relative contribution of each type of influence. As previously noted, the primary disadvantage of regression-based residual procedures is that they require moderately large samples.

Different methods of residual analysis in the context of aging can be illustrated with examples from my research laboratory. First consider tasks involving pairs of similar variables that could be analyzed in ANOVA, or interpreted with subtraction logic, but instead multiple regression procedures are used to predict the more complex variable from the simpler variable. The predicted value in this type of analysis represents what the two variables have in common, and hence the predicted value of the complex variable can be subtracted from the observed value to form a residual that reflects distinct or unique aspects of the complex variable. The relation of age to the residual therefore corresponds to the unique (specific) age-related effect on the complex variable, and subtraction of the unique age-related variance from the total age-related variance on the variable provides an estimate of the shared (general) age-related effect on that variable.

Table 2 contains results of this type of analysis with variables from the Stroop Color-Word Test, the Trail Making Test, and the immediate and delayed recall variables from the Rey Auditory Verbal Learning Test. The columns labeled age correlation indicate the total (original) and direct (residual) age-related effects, and the columns labeled age variance are proportions of total age-related variance (i.e., the square of the correlation of age with the original variable) that is shared (i.e., the square of the correlation of the original variable with age minus the square of the correlation of the residual variable with age) and that is unique (i.e., the square of the correlation of the residual variable with age). In each case it can be seen that only a small proportion of the total age-related variance on the more complex variable is unique, or specific to that variable. Instead, most of the age-related variance is shared with the presumably simpler variable.

This pattern of results suggests that there are little or no unique age-related influences on processes hypothesized to represent what distinguishes each pair of variables (e.g., inhibition of irrelevant information, switching between sequences, or retention of information over a delay). However, because it is relative to another very similar type of variable, analyses involving pairs of similar variables reflect a restricted form of uniqueness. A more global type of uniqueness can be assessed by partialling the effects of a variable derived from a completely different type of task, or by partialling the variance common to a wide variety of different variables.

The analytical procedure is frequently known as mediation analysis when a different type of variable is used as the controlled variable, and age-related effects on other variables are examined after statistical control of a hypothesized mediator. Only a few potential mediators have been analyzed in this manner, but analyses with perceptual speed measures as the mediator have consistently revealed considerable re-

TABLE 2

Age correlations before and after partialling the variance from similar variables and estimates of shared and unique age-related variance

Variable	Partialled variable	Age correlation		Age variance	
		original	residual	shared	unique
Stroop Test (Salthouse, 1996b, $n = 178$)					
Incongruent Color stimuli	Congruent	0.655	0.278	82.0	18.0
Stroop Test (Salthouse and Meinz, 1995, $n = 242$)					
Incongruent	Congruent				
Color stimuli		0.568	0.196	88.1	11.9
Number stimuli		0.484	0.095	96.2	3.8
Position stimuli		0.439	0.039	99.2	0.8
Trail Making (Salthouse et al., 1996, $n = 259$)					
Version B	Version A	0.590	0.237	83.9	16.1
Trail Making (Salthouse et al., 1997, $n = 124$)					
Version B	Version A	0.427	0.183	81.7	18.3
Free Recall (Salthouse et al., 1996, $n = 259$)					
Delayed	Immediate	−0.421	−0.101	94.2	5.8

duction in the age-related effects on a wide range of variables after control of perceptual speed (e.g., Salthouse, 1996a,b; Salthouse et al., 1996; Verhaeghen and Salthouse, 1997).

Because of the positive manifold phenomenon, most cognitive and neuropsychological variables can be assumed to have at least some variance in common, and consequently statistical control of almost any variable will tend to reduce the magnitude of the age-related effects on other variables. As long as the controlled variable is related to age and shares variance with other variables, it could be as complex as a measure of general intelligence, or as simple as a measure of the speed of deciding whether sets of letters or line patterns are the same or different. The nature of the controlled variable is relevant for purposes of theoretical interpretation, however, because as variables increase in complexity they are likely to reflect the operation of a large number of processes, and consequently it becomes more difficult to determine which of those processes is primarily responsible for the shared effects that are observed.

Another method of residual analysis consists of partialling variance common to many different variables prior to examining the effects of age on the target variable. Mittenberg, Seidenberg, O'Leary and DiGuilio (1989) briefly described an analytical procedure in which simultaneous multiple regression of all variables on age was used to remove the common variance among a set of neuropsychological variables, followed by a test of the relation of age on the residual variables. This procedure was apparently employed to control any general effects that might be operating before considering the effects of age on individual variables. Few details were provided in that report about the procedure or its results, and the method was apparently not followed up in subsequent studies. However, variants of this analytical procedure have recently been used with cognitive, psychometric, and neuropsychological variables.

The rationale for the recent usage of the method is based on the assumption from the field of psychometrics that the individual difference variance in a variable can be partitioned into common (shared with other variables), specific (restricted to that variable), and error (unsystematic) components. Correlations of variables with one another within this framework can therefore be interpreted as a reflection of the operation of one or more common factors. Aspects of a variable that are not shared with other variables are unique, and reflect specific and error components.

One analytical procedure based on this rationale can be termed the shared influence analytical method. Two major steps are involved in this procedure. The first is to obtain an estimate of variance common to all variables in the form of the first principal component in a principal components analysis. Other methods could be used to represent what the variables have in common, such as the first principal factor in a factor analysis or a latent construct in structural equation modeling, but nearly identical results have been found with each method, and thus it does not seem to matter precisely how the common variance is determined. The second step in the procedure is to enter the first principal component (or another estimate of the common variance), as the first predictor in a hierarchical multiple regression analysis, followed by age as the second predictor. The use of hierarchical or sequential regression means that the second step in the analysis examines the effects of age on the residual variable created by removing the variance shared with other variables from the target variable. Age-related effects on the residual variables in this type of analysis can therefore be interpreted as estimates of the unique age-related influences on the target variable.

Results of this shared influence analytical procedure from two studies conducted in my laboratory are summarized in Table 3. The four columns on the right of the table have the same meaning as in Table 2 except that now the partialled variance corresponds to what all the variables have in common. Notice that, just as in Table 2, the unique age-related influences are only a small proportion of the total age-related effects for every variable.

Similar patterns of small to non-existent unique influences have been obtained with the shared influence method in analyses of age-related effects on a variety of different cognitive variables (e.g., Salthouse, 1996b; Salthouse et al., 1996, 1997; Verhaeghen and Salthouse, 1997), and of effects associated with Alzheimer's Disease (Salthouse and Becker, 1998) and with HIV (Becker and Salthouse, 1999).

TABLE 3

Age correlations before and after partialling variance common to many variables and estimates of shared and unique age-related variance

Variable	Age correlation		Age variance	
	original	residual	shared	unique
Salthouse et al., 1996, $n = 259$				
Letter comparison	−0.493	0.057	100.0	–
Pattern comparison	−0.660	−0.061	99.2	0.8
Digit symbol	−0.655	−0.029	99.8	0.2
Paired Assoc. 1	−0.510	−0.048	99.1	0.9
Paired Assoc. 2	−0.351	0.036	100.0	–
RVLT Trial 2	−0.469	−0.074	97.5	2.5
RVLT Trial 6	−0.446	0.004	100.0	–
Shipley Abstraction	−0.447	0.092	100.0	–
WCST Per. Err.	−0.409	−0.024	99.6	0.4
Object assembly	−0.412	0.042	100.0	–
Block design	−0.468	0.047	100.0	–
Salthouse et al., 1997, $n = 128$				
DD RT	−0.640	−0.028	99.8	0.2
DS RT	−0.684	−0.052	99.4	0.6
SD	−0.469	0.017	100.0	–
XO	−0.493	0.068	100.0	–
Letter comparison	−0.522	−0.052	99.0	1.0
Pattern comparison	−0.546	−0.028	99.7	0.3
Letter fluency	−0.139	0.199	100.0	–
Category fluency	−0.181	0.101	100.0	–
JOLO	−0.127	0.034	100.0	–
Trail Making A	−0.524	−0.028	99.7	0.3
Trail Making B	−0.508	0.022	100.0	–
CVLT All	−0.426	0.017	100.0	–
CVLT B	−0.172	0.040	100.0	–

Note: RVLT is Rey Auditory Verbal Learning Test; WCST Per. Err. is Wisconsin Card Sorting Test Perseverative Errors; DD RT is Digit Digit Reaction Time; DS RT is Digit Symbol Reaction Time; SD is copying S or D; XO is comparisons of X's and O's; JOLO is Judgement of Line Orientation; CVLT All is California Verbal Learning Test sum across all learning trials; and CVLT B is California Verbal Learning Test interference trial. A dash in the column unique indicates that no estimate of unique age-related variance could be computed because the direction of the age-related effect was reversed after controlling for the common variance.

Conclusions

The terms general and specific have been used in several different ways, and consequently it is not surprising that there has been little agreement about their relative contributions to age-related influences on neuropsychological and cognitive variables. Among the usages of the term specific are the following: specific as conditional in the sense that statistical interactions imply that the effects are not uniform but rather vary according to the variable under investigation; specific as selective in the sense that the effects appear to be restricted to some variables; specific as particular in the sense that a discrete aspect of processing is affected; and specific as unique in the sense that influences on one variable are independent of influences on other variables.

The first three usages are based on evidence that the absolute magnitude of the age-related influence differs across variables. The latter usage is based on evidence of independence of age-related influences because if only a small proportion of the age-related effects are independent, or unique, then there would be little support for a specific, in the sense of isolated, impairment. This last conceptualization of specific has been relatively neglected in the research literature, but the distinction between unique and shared age-related influences is potentially very important because interpretations of the nature of age-related effects are likely to vary dramatically depending on the relative contributions of each type of influence.

The correlational data summarized above indicate that very few, if any, neuropsychological variables exist in isolation, independent of other variables, and the results of different types of residual analyses indicate that a similar lack of independence appears to exist with respect to the age-related influences on the variables. The co-occurrence of age-related effects on many different variables raises the possibility that it may be meaningful to refer to a cognitive or neuropsychological aging syndrome in which various 'symptoms' (in the form of age-related effects on different types of variables) are not independent of one another. To the extent that this is the case, the direction of research might shift from the level of symptoms to the level of a more encompassing syndrome. Regardless whether it is productive to think in terms of an aging syndrome, however, the discovery that large proportions of age-related effects on neuropsychological and cognitive variables are shared, and are not unique to a given variable, suggests that an important focus in the future should be on explaining the shared age-related effects that appear to exist.

Several possibilities that might be involved in the shared age-related influences are worth considering, but they should not be viewed as exhaustive, nor necessarily as mutually exclusive. First, a particular neuroanatomical region (e.g., frontal lobes) could be responsible for coordination or integration of processes involved in many tasks. This possibility is similar to the idea of executive processes that have been presumed to be important in many different tasks. Second, the shared effects could be attributable to a critical neural circuit or pathway, perhaps based on a neurotransmitter such as dopamine. And third, the effects could be due to miscellaneous systemic factors, such as arousal, reduction of myelin, impaired blood supply, or diffuse neuron loss, that have global or non-specific effects on functioning.

Many other alternative interpretations for the shared age-related influences are possible, and it is probably premature to attempt to specify which speculation is most plausible on the basis of the existing evidence. Nevertheless, the results discussed above suggest that it is important to distinguish between the shared and unique age-related influences on the variables of interest in order to ensure that the explanations being proposed are at the appropriate level of specificity or generality. If, as the evidence summarized in preceding sections seems to suggest, the majority of age-related influences on many different types of variables are shared, then task-specific or variable-specific interpretations of age differences in neuropsychological variables may have a much more limited role in the explanation of neuropsychological aging than is often assumed.

References

Aftanas MS, Royce JR: A factor analysis of brain damage tests administered to normal subjects with factor score comparisons across ages. Multivariate Behavioral Research: 4; 459–481, 1969.

Anderson JE: The assessment of aging: Background on theory and experiment. In Anderson JE (Ed), Psychological Aspects of Aging. Washington, DC: American Psychological Association, pp. 75–80, 1956.

Anderson SW, Damasio H, Jones RD, Tranel D: Wisconsin Card Sorting Test performance as a measure of frontal lobe damage. Journal of Clinical and Experimental Neuropsychology: 13; 909–922, 1991.

Baddeley AD: Exploring the central executive. Quarterly Journal of Experimental Psychology: 49A; 5–28, 1996.

Becker JT, Salthouse TA: Neuropsychological test performance in the Acquired Immunodeficiency Syndrome: independent effects of diagnostic group on functioning. Journal of the International Neuropsychological Society: 5; 1–7, 1999.

Chapman LJ, Chapman JP: Problems in the measurement of differential deficit. Psychological Bulletin: 79; 380–385, 1973.

Cohen J, Cohen P: Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences. Hillsdale, NJ: Lawrence Erlbaum Associates, 1983.

Craik FIM, Salthouse TA (Eds): Handbook of Aging and Cognition (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates, 2000.

Daigneault S, Braun CMJ, Whitaker HA: Early effects of normal aging on perseverative and non-perseverative prefrontal measures. Developmental Neuropsychology: 8; 99–114, 1992.

Kertesz A: Localization and function: old issues revisited and new developments. In Kertesz A (Ed), Localization and Neuroimaging in Neuropsychology. San Diego, CA: Academic Press, pp. 1–33, 1994.

LaRue A: Aging and Neuropsychological Assessment. New York: Plenum Press, 1992.

Lezak MD: Neuropsychological Assessment (3rd ed.). New York: Oxford University Press, 1995.

Mitrushina MN, Boone KB, D'Elia LF: Handbook of Normative Data for Neuropsychological Assessment. New York: Oxford University Press, 1999.

Mittenberg W, Seidenberg M, O'Leary DS, DiGiulio DV: Changes in cerebral functioning associated with normal aging. Journal of Clinical and Experimental Neuropsychology: 11; 918–932, 1989.

Mountain MA, Snow WG: Wisconsin Card Sorting Test as a measure of frontal pathology: A review. The Clinical Neuropsychologist: 7; 108–118, 1993.

Reitan RM, Wolfson D: A selective and critical review of neuropsychological deficits and the frontal lobes. Neuropsychology Review: 4; 161–198, 1994.

Reitan RM, Wolfson D: Category Test and Trail Making Test as measures of frontal lobe functions. Clinical Neuropsychologist: 9; 50–56, 1995.

Reitan RM, Wolfson D: Relationships between specific and general tests of cerebral functioning. Clinical Neuropsychologist: 10; 37–42, 1996.

Salthouse TA: The processing speed theory of adult age differences in cognition. Psychological Review: 103; 403–428, 1996a.

Salthouse TA: General and specific speed mediation of adult age differences in memory. Journal of Gerontology: Psychological Sciences: 51B; P30–P42, 1996b.

Salthouse TA: Methodological assumptions in cognitive aging research. In Craik FIM and Salthouse TA (Eds), Handbook of Aging and Cognition (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates, pp. 467–498, 2000.

Salthouse TA, Becker JT: Independent effects of Alzheimer's Disease on neuropsychological functioning. Neuropsychology: 12; 1–11, 1998.

Salthouse TA, Coon VE: Interpretation of differential deficits: the case of aging and mental arithmetic. Journal of Experimental Psychology: Learning, Memory, and Cognition: 20; 1172–1182, 1994.

Salthouse TA, Fristoe NM: A process analysis of adult age effects on a computer-administered trail making test. Neuropsychology: 9; 518–528, 1995.

Salthouse TA, Fristoe N, Rhee SH: How localized are age-related effects on neuropsychological measures? Neuropsychology: 10; 272–285, 1996.

Salthouse TA, Meinz EJ: Aging, inhibition, working memory, and speed. Journal of Gerontology: Psychological Sciences: 50B; P297–P306, 1995.

Salthouse TA, Toth J, Daniels K, Parks C, Pak R, Wolbrette M, Hocking K: Effects of aging on the efficiency of task switching in a variant of the Trail Making Test. Neuropsychology: 14; 102–111, 2000.

Salthouse TA, Toth JP, Hancock HE, Woodard JL: Controlled and automatic forms of memory and attention: process purity and the uniqueness of age-related influences. Journal of Gerontology: Psychological Sciences: 52B; P216–P228, 1997.

Schuldermann EH, Schludermann SM, Perryman PW, Brown BW: Halstead's studies in the neuropsychology of aging. Archives of Gerontology and Geriatrics: 2; 49–172, 1983.

Sergent J: Some theoretical and methodological issues in neuropsychological research. In Boller F, Grafman J (Eds), Handbook of Neuropsychology, Vol. 1. Amsterdam: Elsevier, pp. 69–81, 1988.

Spreen O, Strauss E: A Compendium of Neuropsychological Tests. New York: Oxford University Press, 1998.

Tuokko H, Hadjistavropoulos T: An assessment guide to geriatric neuropsychology. Mahwah, NJ: Lawrence Erlbaum Associates, 1998.

Vallar G: Current methodological issues in human neuropsychology. In Boller F and Grafman J (Eds), Handbook of Neuropsychology, Vol. 5. Amsterdam: Elsevier, pp. 343–378, 1991.

Verhaeghen P, Salthouse TA: Meta-analyses of age-cognition relations in adulthood: estimates of linear and non-linear age effects and structural models. Psychological Bulletin: 122; 231–249, 1997.